Backyard Aquaponics

A GUIDE TO BUILDING AN AQUAPONIC SYSTEM

Joel Malcolm

BACKYARD AQUAPONICS

A Guide to Building A Backyard System

© Joel Malcolm
Western Australia
www.backyardaquaponics.com

Table of Contents

Preface 6

Introduction 7

SO WHAT IS AQUAPONICS 8

The Concept 8

Components 8

The Ideal 9

The Dream 10

My Early Experiences 11

DESIGNING AND BUILDING A SYSTEM 14

Tanks 14

Pumps 16

Grow beds 18

Growing Media 21

Grow Bed Irrigation and Draining 24

Running Costs 27

Water Quality 28

Maintenance 30

SYSTEM DESIGNS 32
Continuous Flow Systems 33
Flood And Drain Systems 35
THE FISH 40
Stocking Densities 41
Feeding Your Fish 42
Fin Fish Species 44
Barramundi 44
Goldfish And Koi 46
Black bream 48
Silver Perch 50
Murray Cod 52
Tilapia 53
Pacu 54
Trout 55
Crustaceans 56
Marron 56
Yabbie 58
Fish Conclusions 59
THE PLANTS 60

BUILDING A SYSTEM 64

Building a shelter 64

Flood And Drain Design 72

Building Grow Bed Supports 73

The Drain System 80

The Growing Medium 82

The Irrigation Piping 84

Flood and drain Process 89

Initialising The System 93

Planting the beds 95

Stocking With Fish 96

Conclusions and my Thoughts 99

Thanks 102

Complete parts breakdown for full system as of 2005. 112

Preface

This book draws together information from around the world, from numerous sources, about a range of subject matters concerning aquaponics, with a heavy focus on Australian conditions and Australian species, aimed at a hobby to small semi-commercial system, and most of its stripped back to the basics.

A few years back when I wanted to learn all I could about aquaponics, and how to set up a hobby aquaponic system, there was no real manual or book or any precise help on the subject so it was difficult to implement, and required years of studying and experimenting to learn about different styles and set-ups…. I only wished I could have had something directly related to hobby-sized set-ups, with particular attention paid to Australian conditions. So I've tried to create what I wish I had a few years ago….

I've written this because when I discovered aquaponics, it amazed me, and still does to this day, it just all makes so much sense... When I first started researching, I spent months searching the net for any information I could find, but information was scarce, especially for the setting up of a hobby or small scale system and most of the information I could find was directly related to not only other countries, but also climates different from that in Western Australia.

Friends who saw the systems I had set up, were fascinated by the whole idea and keen to try it themselves. I decided that ultimately this is the sort of information which needs to be spread to as many people as possible who may be interested. I'd like to see every second backyard with an aquaponic system, to take some of the power away from the 'factory' farms that produce substandard products with little nutrients, while degrading the land and polluting our waterways.

Native fish stocks are declining worldwide and we have to find safe ways of feeding ourselves and I hope to spur others to think outside the square, to devise new and better ideas, ways of feeding the world in a more viable and sustainable way than the methods we presently employ in western society.

I don't claim this is a system whereby you can make a lot of money, I don't claim my designs are the most efficient or the most advisable for all situations, each persons situation is different.. I don't pretend to understand all of what is going on in the systems, all I know is that it works for me, and it can work for anyone if they follow the tried and tested methods laid out in this manual.

Aquaponics is the combination of hydroponics and aquaculture in a symbiotic system. I've spent the past few years experimenting with aquaponics in it's many forms. Most of what I researched from the internet was aimed at people trying to make commercial systems, to sell plant and fish products. My interests lie more along the lines of creating something of beauty which is educational and useful as well. By creating medium sized systems which can help supplement a family's food requirements so that people can become less reliant on the more commercial food products which have rapidly diminishing quality, while enjoying the pleasure of an aquaponic system in their own home.

I've written this book over quite a period of time while I've been experimenting with different systems, and I plan to keep adding to it in the future as I learn more myself by experimenting with different designs and applications. Aquaponics is one of those things which the more you play with it, the more you learn, and as you learn more, systems and processes adapt to the new knowledge gained along the way. I can't stress strongly enough that you have to keep an open mind when delving into something new, especially something like aquaponics. Even in a simple system design there are so many variations and factors that influence the system, and because it's a closed loop system, when you change one thing it will have ramifications on other aspects of the system.

So as you bravely move forward into playing with living ecosystems, listen to friends' advice, speak with knowledgeable people, read all you can, and above all use your common sense. Go with your gut feeling, if something doesn't seem quite right then chances are it probably isn't, but always keep an open mind, just because you may not understand something doesn't mean it won't work. Personally I couldn't comprehend exactly how the flood and drain systems would work with two pumps and nothing else, it didn't seem possible because I couldn't quite get my head around it as there seemed to be too many variables to create a stable cycling system without the use of timers and level switches as a bare minimum. But it works, and works beautifully well.

There are a number of chapters in this book dealing with specific areas of aquaponics, the first chapter deals with the basic system concepts, the different components of a system, and the history of aquaponic style systems which can date back thousands of years. Then the chapters become a little more specific in their subject matter, dealing with fish species worth trying to grow in an aquaponic system, plant species, system initialisation and maintenance, and system designs. The final chapter is a photographic journal of building a system in my backyard, it follows step by step how to build your own system beginning from the ground up, including the construction of a pergola to house the system. It covers all the pitfalls I came across during the design and construction, the choices that were made along the way, as well as the reasons behind the decisions that were made.

This is a very personal journey of my learning experience where I'll let you into my backyard as well as my head to see how things can be done.

Chapter

1

So What Is Aquaponics

The basics of what the whole concept of aquaponics involves.

Aquaponics can mean many different things to different people, I guess purely breaking the word down into it's components, aquaponics is the amalgamation of two words, it's a combination of aquaculture and hydroponics. Aquaculture being the cultivation of aquatic animals, in natural or controlled marine or freshwater environments. Hydroponics being the cultivation of plants by placing the roots in liquid nutrient solutions rather than in soil; soil-less growth of plants. These are certainly not new concepts to most people, but the combination of the two into a sustainable, successful biological semi-enclosed system is a fairly new concept, though some may argue the concept is centuries old.

The Concept

The concept seems fairly simple, the fish need clean well-oxygenated water to live and thrive, while plants need water, carbon dioxide, oxygen and nutrients as well as sunshine. So surely we can use the plants to filter the nutrients out of the water, developing a symbiotic relationship between the two, the fish feed the plants, the plants clean the water for the fish.. The concept is mimicking nature, yet in a more compact enclosed scenario, in reality it's almost a micro system of a pond, stream and field ecosystem, plants absorbing nutrients out of the water as the water flows down streams, or from plants at the edges of ponds and lakes. With fish adding nutrient to the water, the water then being pumped back up to the top of the cycle again, and dropping in the form of rain, a constantly cycling balanced system.

Components

There are three main elements to aquaponics and all three are essential for success, firstly there's the fish, then the plants, so what's the third essential element? Bacteria. As the fish breath they give off ammonia through their gills this has to exit the system somehow. Ammonia is of no use to plants and this is where the microscopic workers, the bacteria, come into play. Two main types of bacteria break down the ammonia in the water. Nitrosomonas bacteria break down the ammonia (NH_3) into nitrites (NO_2), then Nitrobacter bacteria steps into play and oxidises the nitrite into nitrate (NO_3) . Nitrates are a form of nitrogen which plants can use, extracting it from the water and thus cleaning the water at the same time. Other nutrients essential to plant growth such as potassium, phosphorous, magnesium etc come from the food fed to the fish, the faeces of the

fish is broken down by numerous other micro-organisms, releasing these other essential nutrients and elements. All three are vital components to the system of aquaponics, the fish, the plants, and the bacteria and micro-organisms.

The Ideal

Vegetables and herbs on the back patio, organically grown, without any fertilizers. With only around $1/10^{th}$ of the water used in traditional vegetable growing methods. No discharge, no run off, not even any sand or soil, grown year round at a comfortable height for planting and picking, and if you have your system in a green house, you can grow vegetables and herbs all year round no matter what the weather.

Figure 1 About 5 weeks of growth from seedlings planted in the grow bed

By the very nature of the system it has to be organic, you can't spray the plants or it will effect the fish and the bacteria, you can't treat the fish with any chemicals or you'll effect the plants and bacteria.

Natural systems in your own back yard for minimal input, and the design possibilities are endless, systems can be small enough to sit on your windowsill, and large enough to create a successful business supplying fish, herbs and vegetables.

Figure 2 Black bream, looking happy and healthy even if the picture isn't the best quality

Fresh fish on your doorstep all year round, marron, yabbies, red claws, even eels if that's your fancy, growing together with the plants in a symbiotic relationship, with no expensive set-up or running costs, a centre piece for any yard, house, business, wherever you have just a little space, or a lot of space.

Adaptable to however much space or money you have to implement the system. Systems can be designed with future expansion in mind, they can be designed to fit into a particular landscape or theme, the possibilities and variations are almost endless, from an aquarium to a pond, to a purpose built commercial system.

The Dream

Picture it now, just outside your back door is a beautiful pond, reflections of the garden beyond shimmer across the surface of the water, broken only by bright green lily pads and a brilliant pink lily flower, so perfect in shape and form as it emerges into the open from the depths of the water.. An insect meanders on the summer breeze gliding down to the water surface for a cool drink at the edge of a lily pad, when splash, the pond surface erupts with a powerful burst, the fish below had seen the insect settle down for a drink and now the insect is gone in a flash in a flash of silver scales, nothing but a quick snack. As quickly as the excitement began, calm is returned all is peaceful again, apart from the trickling of the water flowing back into the pond.. And the fish below the surface of the water go about their daily routine, weaving between the lily pad stalks as they meander on their endless search for food..

The water's crystal clear, a large marron pushes his black claws out from his hiding spot, and the Murray cod pokes his head out from the pipe he's been hiding in, the large silver perch are tussling, chasing each other lazily trying to defend their little spot in the tank. While the large black bream swim around gracefully, ignoring most of what's going on around them, their eyes swivelling in their sockets as they calmly scan the other activity around them…. The plants in the grow bed are booming, lush new growth can be seen each day, as they

tirelessly go about their work helping to filter the water for the fish. Fresh herbs are flowing out over the sides of the grow bed, mint and basil so pungent their odours waft on the summer breeze as if they were flowers. Fresh red tomatoes are ripening and filling with colour and the red capsicums are so heavy it looks like they'll pull the plants over… Animals and plants growing together in a symbiotic nature, as they should, all right at your back doorstep and you did it all yourself, this is what greets me every day on my back patio.

My Early Experiences

My experiments in aquaponics began very humbly. While searching the net for different ways of growing plants I came across the aquaponics list run by Paula and Tom Speranio; this is an invaluable source of information as people from all around the world post the questions, theories, thoughts and answers, it's a real melting pot of ideas which is essential for the successful implementation of something like aquaponics which has so many variants and variables that no two systems are ever exactly the same.

I began scanning through archives and searching the web for information on how this all worked. It just all seemed to make so much sense. I have always been motivated by using natural systems for food production, now here was a system which would reach new levels, fish and plants growing together in a symbiotic relationship, with no effluent of any sort. Only how to begin?

Figure 3 My first setup, a rather sad inflatable pool

I had a very cheap inflatable pool, which had been used for a couple of years already as a swimming pool, and still held water. Add a couple of trestles standing in the pond, with three large tubs full of hydroponic expanded clay, holes drilled in the bottom of the plastic tubs, and a cheap pond pump to pump the water from the pond up through the tubs. As the whole system was under the back patio I used a few shade loving 'house' plants and ferns in the gravel tubs, as well as a large number of plants in the actual pond, water lilies, taro plants, Chinese water chestnuts and liberal amounts of duck weed floating on the surface..

However, it didn't last long, as you can see in the figure 3 the dark blue inflatable ring soon sprung a leak, the pond still stayed in place, but every now and then leaks over the edge were inevitable, causing much stress and heartache as I desperately tried to plug any overflows which appeared by using wires to string up the sides of the pool. The next phase was required.

After many phone calls and a fair amount of driving around visiting plastics manufacturers and fibreglass tank producers, I settled on the idea of a galvanized iron tank for a few reasons, firstly and foremost, price, it was the cheaper option by almost 1/3. Secondly, for aesthetics, a plastic or fibreglass tank doesn't look highly attractive, where as the corrugated iron tank had character, and was more apt if it's going to sit in the middle of my back patio; after the blue blow up pool fiasco I wanted something with a little more class..

Figure 4 Corrugated Iron tanks for the fish tank, and for the grow bed was a good option

The tank manufacturer was quite interested in what I was trying to do , and I think he figured I was maybe just a little crazy. When I explained what I wanted in the way of a grow bed, he felt assured I was crazy, 'You want a tank only 300mm high, with a hole in the bottom?'

Once I had bought the tanks it only took a weekend to set most of it up, including building the grow bed stand, and sorting out all of the plumbing, which is all available off the shelf from the local reticulation store, including the pump (details of all materials are included later in this manual). Of course this weekend was filled with many mistakes, swearing, cursing etc, as I really had not much of an idea of what I was doing, I'd never built a tank stand before in my life, and just how heavy was the grow bed going to be, filled with gravel and water?

In both the set up of this system with the corrugated iron tanks, and with the original inflatable pool system, I was a little distressed at the algal build up for the first few months after the systems were first set up. In Figure 4, I had placed a steel bar across the top of the tank from which I suspended a mesh bag, and even a t-shirt to

try and capture some of the algae that was suspended in the water. This didn't really work, and it was just a matter of time before the system reached an equilibrium and the algae cleared, this can take up to 3 months in a new system which can be very disconcerting, and when the water finally does clear it's a great relief. Patience is the name of the game, be patient, and things will eventually reach a balance.

.

Chapter

2

Designing And Building A System

The elements required to build a system, including a few variables to set you on your path.

Sytems are generally made from two basic components, you have to have your tank/pond/dam/aquarium, which houses your fish and is your basic water reservoir, then the grow beds/hydroponic guttering/reed bed/raft system etc, which ever is your preferred method of plant growth. The style of plant growing I deal with here in this manual are aggregate filled grow beds, which are covered in more detail later in this chapter.

Tanks

Tank types are totally up to the individual and the requirements of their systems, or whatever is readily available or within the budget. Of course the ultimate would be to buy an aquaculture tank, specifically designed for the purpose, they include styles with conical bottoms and sumps incorporated into the base so that all excess feed sediment and fish poo doesn't get a chance to build up in the tank as it settles in the base and is pumped away immediately. As well as the conical bases there are the more standard flat bottom designs of all shapes and sizes, including round and square tanks.

Figure 5 large fibreglass tank purpose built for aquaculture

There's a wide range of designs and sizes and they can be constructed from fibreglass or from plastics depending on the manufacturer. One advantage of a plastic tank over the corrugated iron version is that you can have 2/3, or most of the tank resting on a board slightly above the normal ground level, allowing a section to the side of the tank to be at a slightly lower level (Figure 6).

This can be useful as the sediment in your fish tank will drop to the lowest point and if your pump is down in this depression then there is a constant pumping out of sediments as they settle. In a basic system set up this will mean that the sediment is pumped into your grow beds.

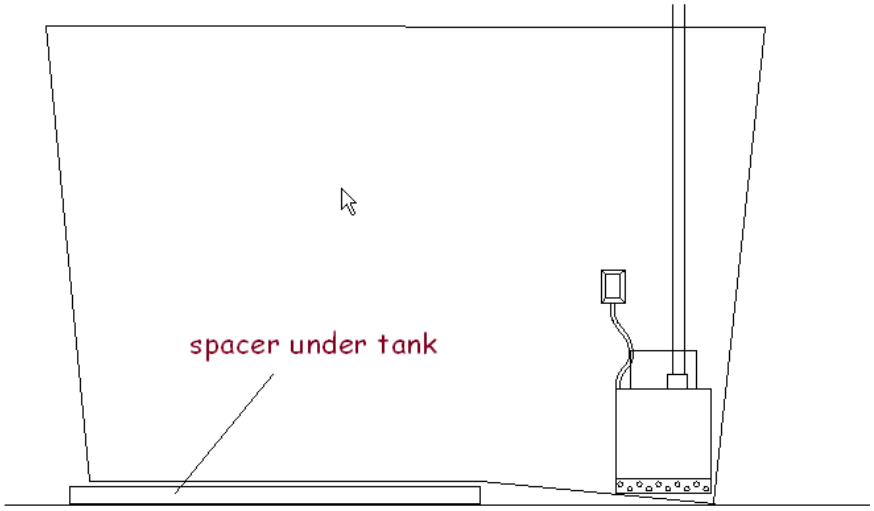


Figure 6. Spacer boards under a plastic-poly fish tank, allowing sediment to settle near the pump

Realistically, your tank might be whatever you can afford, and how big you want the system to be. When you set your mind to it there are many second hand items you could use for a tank. Two hundred litre plastic drums are available for a nominal cost from rural supplies stores, and although they will need cleaning, they are made of food grade plastics and are generally used for storage and cartage of foodstuffs and non-toxic liquids, and they are cut in half for animal feeders and water troughs. Cutting these drums is easy with a jigsaw, and you can use them in a variety of ways, just take the top off one end for a maximum volume tank. You could cut them in half for two small tanks, or you can cut them length ways for two great grow beds. Another cheaper option is a 'bulky bin', 1000 litre square plastic containers which have galvanised steel cages around them and they are less than half the price of a plastic one. But personally I like the galvanised iron tank for it's functionality, price and style.

Some people use the plastic swimming pools, very similar to the pool I used in my first experimental set up, these are being used in a variety of ways for both fresh water crayfish and for fish and some people have had many years of use from these pools before they have begun to deteriorate. Care must be taken if you decide to use one of these pools, to clean it before putting fish into them.

Figure 7. A simple inflatable pool can be a moderately cheap temporary option

Generally cleaning out with some dilute chlorine and a scrubbing brush will be sufficient, though it is also recommended that they be left out in the air for at least a couple of weeks in case of any gasses and residues which may be given off from their plastics which are used in their construction. I found when I bought my inflatable pool it was almost the same price as the corrugated iron tank I bought, and the quality just doesn't compare.

Pumps

The pump of my choice which I have used in most of my systems is an ‘EBARA, best zero’, a solid little pump made from stainless steel, manufactured in Italy and powered by a sealed 250W motor, it can pump 125 litres per minute at a head of 2.7 metres.

The flow is so good that it’s a little too much for a small single bed design with a continuos flow of water, it doesn’t get time to drain through the gravel and you can end up with flooding problems. This can be easy to fix with the incorporation of a valve just before the grow bed so that I could throttle back the flow a little. Initially I thought it would be detrimental to throttle the flow of the pump by restricting the outlet, but for these pumps it’s not a problem.

The pump can handle particle sizes up to 10mm, which is about the size of the holes in the intake at the base of the pump, this is very handy as any gravel and other bits which might get into the tank are not going to kill the pump, instead they will be pumped straight through and eventually end up back in your grow beds.

Figure 8. The stainless steel pumps I use in most systems.

In smaller systems, it might be more practical to use a smaller purpose made pond pump, these come in a huge variety of shapes and sizes, most with reasonably low pumping rates and maximum pumping head, one that I used in my initial set up was a ‘Pond master 1000’, a very small 20W pump which at a pumping head of around

1.5 metres can only pump about 500 litres an hour. It's cost was about half that of the stainless steel Ebara pump, but it's flow wasn't enough for the larger system.

It's easier to cut back the water flow if it's too much by using a valve rather than finding a smaller pump is insufficient and having to replace it or buy a second pump, so keep this in mind when shopping for a pump. You may decide to modify your system and add another grow bed or some hydroponic guttering for added plant growth and filtering, and already having a pump which is bigger than you really need, means that you can easily modify your reticulation to allow for extras without having to update the pump for more flow.

Then of course there is also the aspect of running costs, a 20W pond pump is a lot easier on your pocket than a 250W pump. Solar powered pumps are a possibility but check your system as the flow rates of DC pumps are generally far less than conventional AC powered pumps. This is an area of aquaponic design where more work and research needs to be carried out, so that systems can be designed to work separately from the power grid.

It wouldn't be too difficult to design a system using only one solar pump to fill an elevated reservoir, when the reservoir fills to a sufficient level the water can be released to flood your grow beds, much the same as a toilet cistern works, draining directly back into your fish tank. An Automated syphon release can be set up on the raised header tank, though this requires some experimentation to have flow rates and pipe diameters correctly sized to make the syphon work.

Grow beds

Grow beds are a container with a drain hole, filled with a medium like gravel, the water from the fish tank is irrigated onto the gravel surface. The water drains through the gravel and out of the drain hole and either into a drain tank, or straight back into the fish tank. The bacteria live in the gravel and extract the nutrient from the water as it passes through the gravel. The bacteria need to be protected from sun light, this needs to be taken into account when working out the depth of your grow bed, 12 inches or 30cm has been shown to be an optimum depth for medium in a grow bed, allowing sufficient room for root growth, water flow, and also most importantly, bacteria growth.

a) Corrugated Iron

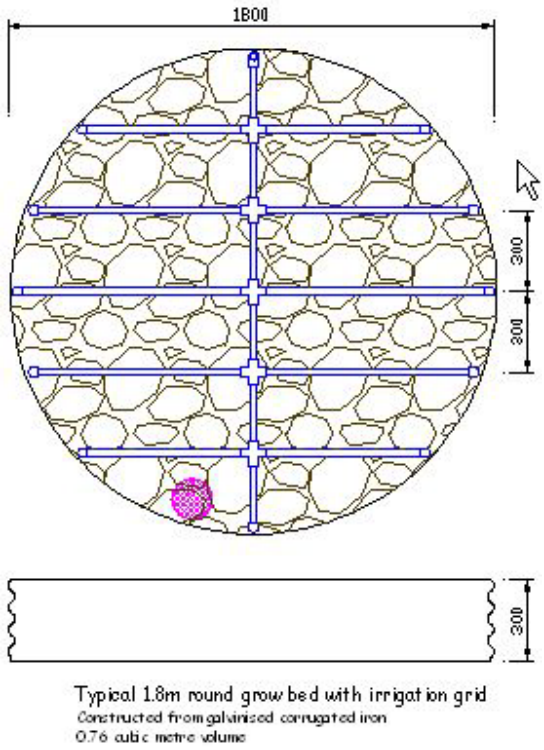


Figure 9. My choice of grow bed, the round corrugated iron bed.

Corrugated iron tanks are reasonably cheap especially here in Australia. They are widely available, as in Australia corrugated iron water tanks are manufactured in all major cities and most reasonably sized towns. It's a fairly straightforward task to explain to the tank manufacturer what you require, and I have included detailed photographs and diagrams throughout this manual.

Size of grow beds are very flexible as tank manufacturers make to your specifications and drain fittings are attached as required by the manufacturer, or by yourself. I have used a range of different sizes from 1.2m diameter up to 1.8m diameter, I wouldn't go much larger than 1.8m as you have to keep in mind that plants are going to be grown in these beds and you have to be able to reach the centre of your grow bed with ease for planting and harvesting. I found the tank manufacturer I used to be very receptive and very interested in what I was using them for as well as letting me know ways of reducing costs by changing sizes slightly to reduce joints in the steel which would increase costs..

The only disadvantage of the round grow bed is in system design layout, if your system is to be set up in a square or rectangular green house the efficiency of laying out circular beds which have a round foot print, in a square or rectangular housing area is nowhere near as efficient. Though personally, if this is not a major issue to your project I find the round grow bed much more aesthetically pleasing than a square or rectangular grow bed. They are available in a wide range of colours as are normal water tanks and there's no doubting their safety so far as leaching chemicals or gasses into your system, as their intended purpose is for storage of drinking water.

b) Plastic lined wooden boxes

Many aquaponic systems set up in the United States, are based on the S&S model which generally includes 4 to 6 grow beds per tank of fish. S&S Systems where developed by the Speranio family of Oregon, who have been divisive in experimenting with aquaponic systems, and designing cheap simple systems which work exceptionally well.

In a typical S&S system, grow beds are generally around 1.2 metres by 2.4 metres by 300mm deep rectangular beds often made by such means as using old doors or thick marine ply for a base then using pieces of wood 300mm by 50mm to make the side frames, once the basic box frame is made then a drain hole of about 2 inch diameter is drilled through the base at one end of the bed. The grow bed is supported on a frame of 100x25mm timber or similar, depending on the application or availability, then lined with pond liner or equivalent. The level is checked to be sure that there is a fall down to the drain end of the grow bed, and once the drain has been suitably sealed and the pond liner is in place it can be filled with growing medium.

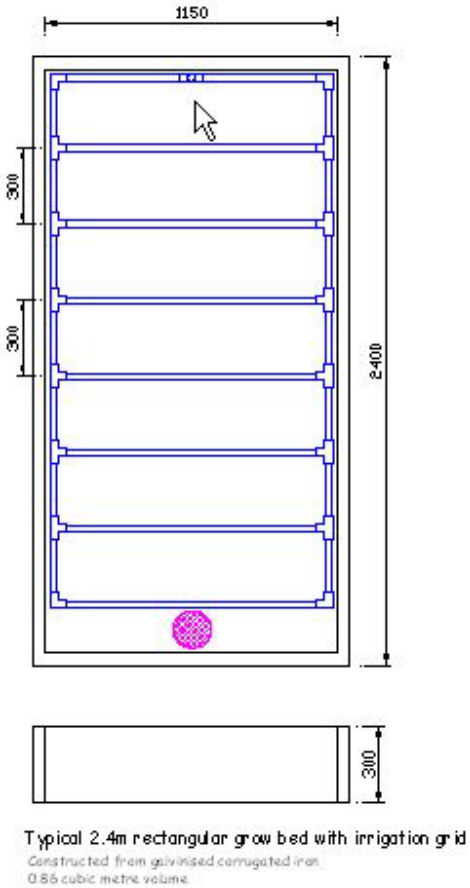


Figure 10. Square beds are more economical on space.

These grow beds can be very cheap to construct, and their rectangular shape makes them ideal for maximum space usage in green house conditions, as greenhouse structures are not cheap. The box work of the bed must be screwed together to ensure it won't break under the strain of the gravel and water. The whole bed then needs to be supported by a framework of 50mm by 100mm timber or similar. Once the garden bed box has been constructed it should be painted with a waterproof exterior paint, then lined with plastic so the whole bed is waterproof.

c) Moulded plastic

Another alternative for grow beds is moulded plastic, so long as the container is of food grade plastic, as any leaching of chemicals and gasses from plastics which aren't food grade can contaminate the plants or worse still kill the fish.. In the US, there are a few manufacturers who make and sell plastic beds specifically designed for this purpose. I have been unable to find a supplier in Australia who sells a similar container. Hydroponic trays of a similar length and width are available, however they are only about 5-10cm deep, which is too shallow to allow the bacteria to grow reasonably.

d) Other methods

Grow beds can be made out of many varied things, it's just a case of using your imagination and looking around at what is available to you, like in my earlier example, plastic tubs. These were very easy to use as well as convenient and cheap, once again it all depends on your application, the plastic tubs were ideal for my situation as they were located directly above the water tank and all I had to do was drill many holes in the base of the tub, allowing them to drain directly back into the water below. Large 200 litre blue plastic water drums cut in half down the length of the drum leaves you with two great 100 litre grow beds, so long as you support them, well as with rounded bases they are liable to roll.

Systems can use methods other than grow beds, methods like floating rafts or NFT guttering are commonly used in aquaponic systems, both on their own and in combination with other methods. Floating raft systems are ingenious in the design and practicality, nutrient rich fish water flows down a long wide channel which could be pre-constructed moulded plastic, or as simple as two raised edges of brick, timber, concrete etc, laid on the ground the desired width apart, then plastic liner run down the length of the channel. This creates a long shallow waterproof channel that is filled with water gradually being pumped in one and draining out the other end into a drain return tank. Large pieces of polystyrene foam cut to the correct size to fit into the channel then have a number of holes drilled into them, seedlings are then placed into small hydroponic baskets filled with perlite of similar. These are then fitted into the holes in the polystyrene so the roots are suspended below the foam in the little basket of perlite. These foam rafts are then placed into the channel, floating on top of the nutrient rich water, newly planted foam rafts are placed in at one end, while mature plants are taken from the other end of the channel. Once this system is underway it becomes fairly easy as the harvesting is always done from the bottom and the newly planted rafts are placed into the top end each raft slowly progressing down the channel until it's fully mature down at the harvest end.

NFT (nutrient film technique) guttering looks a little like normal house guttering with a lid, and is used extensively in hydroponic systems and works well for an aquaponic system. All of the fittings are readily available from hydroponic shops, this has the added advantage that it can be stacked vertically, or on A frame, thus helping to maximise growing space.

One of the only methods of hydroponics that is very difficult to use in an aquaponic system is aeroponics. Aeroponic systems work by having the plants roots suspended in large boxes that exclude light from the root zone, inside these boxes are misters that mist water with high nutrient levels directly onto the roots of the plants. Although this is a very successful method of growing plants in a hydroponic situation, once you incorporate fish into the equation water quality becomes a problem as the misters in aeroponics require very clean water as they clog very easily.

My personal preference is to follow the growing media bed type system, but this is only my personal preference, and the area I have had most experience.

Growing Media

There have been many years of experimenting in many types of grow beds by many different people around the world it has been found that one of the best things to fill your grow bed with is gravel, with a particle size of between 5mm and 10mm. This size of medium has been recognized as the best to use as it all relates to the availability of oxygen and the surface area for the bacteria to grow on, you need to have optimum conditions for bacterial growth, and the bacteria grow on surfaces, mainly the surface of the pieces of gravel as well as the sides of the fish tanks and grow beds. Perlite doesn't perform so well as it tends to break down, get crushed and ultimately it floats, and in a flood and drain aquaponic system, this isn't a good thing.

Very coarse sand works to an extent but it's only a short while before it becomes clogged with roots and/or algae, then water flow is restricted, there is also less air available for the plant roots when smaller particle sizes like sand are used, besides gravel is available throughout the world and is normally very cheap. You must be careful to rinse it very thoroughly before using it though as it's easier to remove the dust and dirt before pumping it into the fish tank. This can be done if you have control over your return flow of water by simply pumping water out of the system from your drain tank rather than back to the fish tank, pumping away all of the dust and rock chips.

Figure 11. Hydroponic expanded clay

In smaller systems which drain directly back into your fish tank, it's a little more difficult, an easy method of cleaning the growing medium is to tip the gravel into a large plastic tub with holes drilled in the base of it. Hose the gravel well mixing it around from side to side until the water draining from the base of the plastic tub becomes clear of any dust or debris, it takes time but it's well worth spending more time at this stage being sure that it's as clean as possible, rather than trying to extract the dust and debris once it's all in your system.

Hydroponic expanded clay is an ideal medium, light weight, perfect size, but very expensive, and out of the equation unless you have a lot of money and need a light weight medium. I have a mixture of some expanded clay in one of my beds, mixed with cracked pea gravel, but this is only because I bought a couple of bags for my initial experiments with the blue plastic inflatable pool.

Figure 12. Cracked pea gravel.

Cracked pea gravel is what I have used in one of my grow bed, it's very cheap to buy and available from most landscaping suppliers in bulk. The cracked gravel can be a little hard on your hands when your not used to it, and it takes a little practice to get the hang of planting in such a course medium, especially if your used to planting seedlings out into normal garden dirt.

For price and availability, there really is no comparison, I guess it is a personal choice as to whether you decide to use the cracked pea gravel, or round gravel, cracked gravel has a slightly larger surface area and as such can support a larger population of bacteria. In a more recent system I built, I decided to use the round gravel to save my hands from the punishment of digging into the cracked gravel, this system had a much larger total grow bed volume, and I really didn't fancy having to plant out hundreds of seedlings into the course rough gravel.

There has been some mention as to whether river stones of a similar particle size would be suitable for use. River stones may be great to look at, and they would also be much easier on the hands to work with because of their smooth surfaces, but these smooth surfaces mean not as many nooks and crannies for bacteria to grow, basically once again, less surface area.

If your thinking about using media other than those I've mentioned keep in mind the basics that have been tried and tested over time, average particle size should be between 5 and 10 millimetres to allow for root growth and air gaps, and avoid media which will break down too quickly like perlite.

You could try experimenting with many different substances if you are building a system that isn't along the lines of the designs I have mentioned in this manual, some people are experimenting with mixtures of coarse sand and peat, others with coconut fibre or rock wool.

Then again, you may decide to not follow along the path of the grow beds at all, perhaps you'd prefer to try using floating polystyrene rafts or Nutrient Film Technique (NFT) guttering.

Grow Bed Irrigation and Draining

It's important to irrigate the fish water evenly over the grow bed so that all plants receive sufficient water, and fish effluent/old fish food/algae pumped through the system. In the designs I'm dealing with in this manual, 25mm poly pipe is used in a grid pattern spaced at 300mm spacings over the whole bed.

Figure 13: Irrigation piping detail.

I don't glue the main fittings on the grow bed, so that they can be removed for cleaning if required, 6-8mm holes are drilled in the under side of the pipes at a spacing of about 15-30cm. It's important that the holes are in the underside of the pipe, other wise the nutrient rich water will be exposed to sunlight and algal growth will build up in the beds and become a problem. The object is for the water to be applied directly to the gravel and the irrigation grid pipes can even be partially submerged in the gravel, to exclude sunlight from the nutrient rich water.

For a single bed hobby system, water is irrigated onto the bed, straight through, however as you include more beds into the design, ways of controlling the flow to individual beds must be incorporated into the design, if any bed is further from the pump than any other, or at a slightly higher or lower level, the flow to different beds will be uneven. This is simply rectified by installing a hand-operated valve just before each bed. Any bed receiving more water than others can be throttled back a little with the valve until an even flow is distributed to each bed.

Just as important as the application of water to the grow bed is the removal of water. Which ever type of grow bed you have you must ensure that your drain is accessible, so that it can be cleaned easily if it gets blocked with roots or other plant material. With bottom draining grow beds a shower or bath drain grill works well. In one of my grow beds I have used a small piece of plastic gutter guard mesh siliconed firmly in position over the drain hole this has worked well for a couple of years without a hitch..

But how do you get to the drain which is in the bottom of the grow bed if it's covered by growing medium? I use a piece of 150mm poly pipe about 350mm high, the poly pipe is drilled with numerous 5-7mm holes and placed vertically over the drain hole, into the grow bed before being filled with the growing medium. You can see whether there are any obstructions in the drain at any time. If the holes in this pipe become a little clogged, its easy to free it up by rotating the pipe backwards and forwards to break any roots or dislodge sediment in the holes and allow the water to flow freely again...

Returning drain water to the main fish tank can be done in two ways, firstly and most simply, is to have your grow bed or beds higher than the level of the fish tank, this way the water will flow back into the fish tank under gravity . This can be done through either overlapping the drain end of the grow bed over the fish tank so that water drains straight in, or by piping the water to the fish tank, through a drain poly pipe.

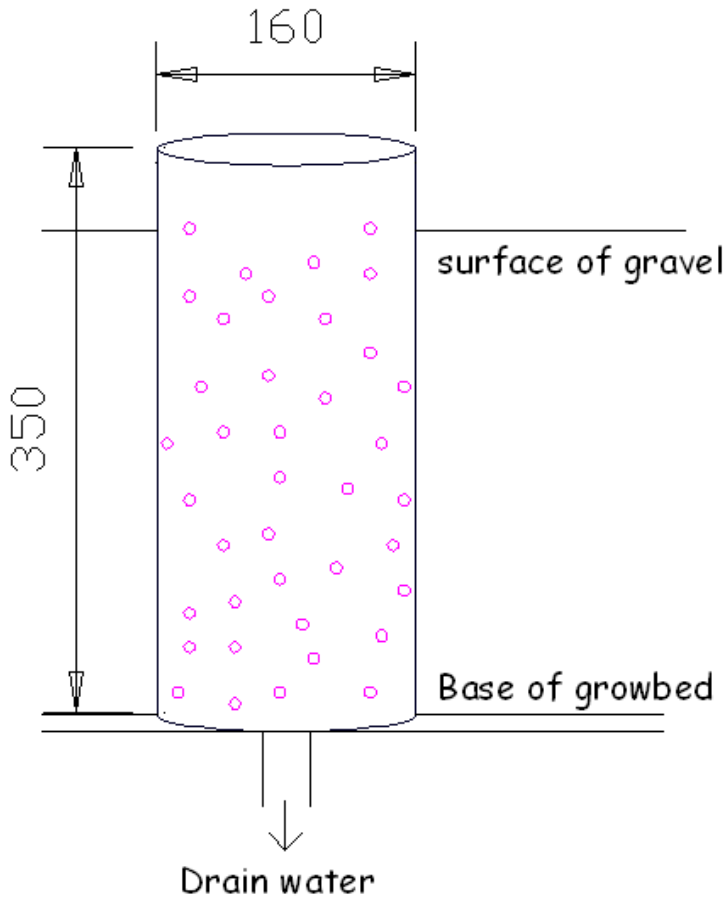


Figure 14. Typical grow bed drain

However this isn't always possible. Your tank may be too high to keep the lowest level of the grow bed above the fish tank water level. If this is the case, a small sump tank may be required with a second pump for pumping the water back into the fish tank. This method works particularly well if you have many beds. It's not feasible to have them all draining back into the fish tank under gravity unless the fish tank is below ground, however it also means that there is another point of failure if the pump breaks down.

The best pump for the purposes of drain return has to be a drain pump with a tethered float switch; this way return water is pumped automatically when it raises to a sufficient level, activating the pump. It switches off automatically when the float switch drops with the water level. This drain tank can be as simple as you like I have used a 50L plastic tub available at most general stores or supermarkets very cheaply. Or conversely if aesthetics are important and you have used the corrugated iron tank and grow beds, then there is little extra cost in getting a small return tank made as well at the same time as the rest of the system is being made up.

Figure 15 shows the way in which the water flows in a system, blue arrows indicate water being pumped from the fish tank to the grow beds. Green arrows are indicating the water irrigating the grow beds, flowing through the gravel and out the drain pipes into the sump tank, when the sump tank fills, the pump starts and pumps the water in the direction of the purple arrows, back to the fish tank.

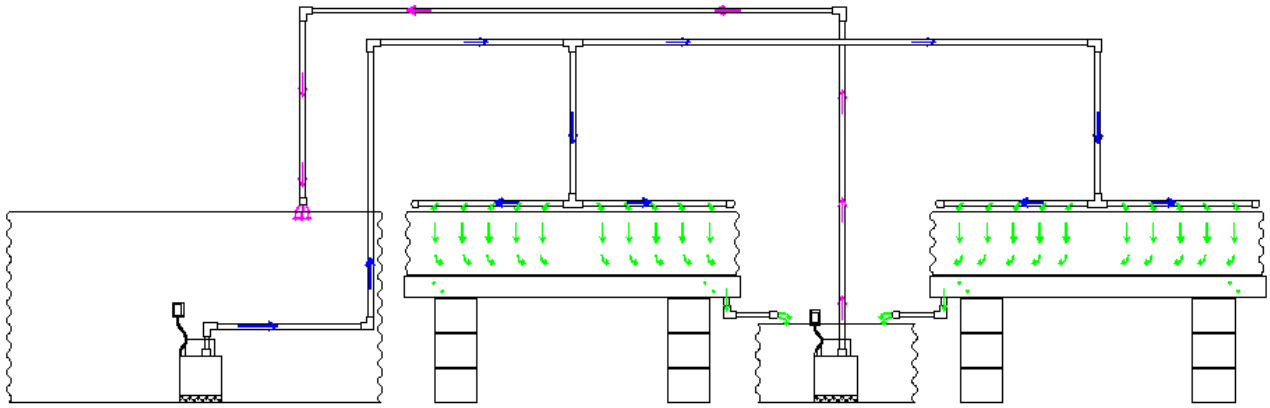


Figure 15. Basic flow of water in a flood and drain multi bed system.

Running Costs

Running costs for your aquaponic system will depend on your pump size and frequency of operation. A continuous flow system based on the pumps I have recommended, if the pump is left running 24 hours a day is expensive if you are using the larger pumps. To reduce the cost you can use a simple timer .It costs very little, and is available from most hardware stores and department stores. The timer plugs into the normal power socket, then the pump plugs into the front power outlet on the timer. On and off times are set in increments of 15 minutes over a period of 24 hours, and there is also a manual on switch on the side of the timer.

A larger flood and drain system doesn't require timers, and is often cheaper to operate than a continuous flow system that is on permanently. Even though the flood and drain system has two pumps, they operate intermittently. My four grow bed system has two pumps, but they only run 30% of the time.

When installing a timer in your aquaponic system to turn the pump off and on you should remain aware that the best time to have the pump switched off is during the day. During the night plants switch from using carbon dioxide and producing oxygen, to using oxygen and producing carbon dioxide, so algae in your tank will sap oxygen out of the water. Critical times for low oxygen levels in your aquaponic system will most likely be during the evenings and early in the morning. If you are going to use a timer to cut down pump running cost be sure to keep an eye on your fish, and try to keep 'off' periods during the day time.

Figure 16. Timer for simple pump control.

Possibilities of using a solar system could be worth looking into, this may require a little more up front expense as you have to buy batteries and solar panels but then there are little to no ongoing running costs involved.

Water Quality

Te Success of your system depends on maintaining water quality.

When you visit a pond or aquarium shop you'll find shelves and racks full of testers and test kits, electronic versions, papers or powders, and little bottles of assorted liquids, and colour charts for every conceivable water quality issue. You may have used these before, you hold your water sample up and try and judge which colour your water matches after it has been treated with the appropriate little bottles. Sometimes I have struggled to pick which colour mine matches up with, figuring that hey, well it has to be one of those 4 or 5 different shades, which could mean my water is ok, or then again maybe not..

At home I have a shelf filled with bottles, jars, tubes, booklets and charts, for testing pH, dissolved oxygen, nitrates, and nitrites, and I use none of them. I have found that nowadays I use the most useful testing instruments I have, my nose, eyes and common sense. I haven't used any water testers in almost a year. In my small continuous flow system, the pump is set on a timer and over a 24 hour period it's generally pumping for around 12 hours, this was fine over winter, but as the weather warmed up and the fish grew I could see that water quality was declining, as the water became more cloudy with algal build-up. Simple to fix, flick the little switch on the timer to manual so the pump stays on 24 hours a day and within 2 days the water becomes crystal clear. I then switch it back to automatic for a while and let it cycle on and off for a couple of days and then give it another burst of a few days on 24 hours a day, this has kept the water beautifully clear without any problems.

Sometimes you may want more instant results in fixing very cloudy water, this is why it's a good idea to incorporate into your design a pump-out gate valve on the grow bed.

I have one near the edge of my fish tank, as the water is pumped out from the fish tank towards the grow bed, there's a simple T-piece and a gate valve leading off to one side so when ever I want to change some water it's as simple as flicking the valve and water is pumped straight out into the garden. It's handy to add a hose attachment to this valve as the water is very nutrient rich and great to spread around your garden.

Figure 17: Outlet valve for flushing water out of the system.

Every now and then you might need to flush some of your water out and replace it with fresh water, like when friends come around and the kids throw handfuls of food into the system which doesn't all get eaten. Within a day or two the water quality is heading down hill at a rapid rate, a quick exchange of about a third of the water will sort this out a treat.

Feeding effects water quality to a great extent. The more you feed the fish, the more nutrient is being incorporated into your system, so if your water quality looks like it's on the decline cut back on the feeding for a day or two, increase water flow if it's not already on 24 hours a day see how this goes. If water quality is still declining change some water by pumping some out and topping up your tank with fresh water.

If you're not used to keeping aquaria or ponds and you're not too sure about water quality and what might be good or bad, it doesn't take long to become tuned in to your system. The water should smell clean or have a very slight 'pond' smell, and it should be reasonably clear. The clarity of water may depend on the age of your system, if your system is less than three or four months old then algae build up and cloudy water are the norm. Once your system has reached its balance and the water clears, which will be anytime within three to four months, it shouldn't ever get cloudy again or have any noticeable algal build up in the water. Of course there will be some algal growth on the sides and bottom of the fish tank but there should be no problems with algae suspended in the water. If there is, then there's not enough filtration of the water or there has been excess feeding, and you have to increase pumping times and/or change some water.

If your pumping twenty four hours a day, and not feeding too much, then you must have stocking densities too high for your system, and the grow beds can't keep up with filtering the water. In this situation you will either have to remove some fish, or add some more grow beds or filtration of some type. Always keeping in mind that stocking densities should be at about a maximum of 250g per 4 litres of water, or just over 6Kg of fish per one hundred litres. These stocking densities are recommended for a system that has twice the volume of grow bed to fish tank volume.

Water quality and more specifically dissolved oxygen levels are the factor limiting fish stocking densities, if you have stocking densities at about maximum levels, then you have to be reasonably sure that nothing will go wrong and effect your oxygenation of the water. Additional bubblers can be added to your fish tank to ensure that oxygen levels are kept at a premium. One sure sign that there is a problem with oxygen levels is if your fish are at the surface of the water gulping air, if you see your fish doing this then you must take immediate action, to increase oxygenation, even if it's as simple as using a bucket to scoop water up and pour it back in, splashing and oxygenating the water. Oxygen levels can be a problem if you have a power blackout or pump failure, and the higher your stocking levels the worse the problem can be as the water will deteriorate quicker. I plan on using a 12V solar powered air bubbler as a backup in my system as the fish mature, just as a backup in case the power goes out for a few hours or a pump fails, at least this will keep the fish alive for a while until I can do something about fixing the problem.

Depending on your locality you may have very poor quality scheme water. It is recommended that chlorinated scheme water be left standing in an open tank for twenty four hours. Over twenty four hours the chlorine will evaporate from the water. If the chlorine levels in your scheme water are fairly high the chlorine can be detrimental to the fish, and kill bacteria in the grow bed. However the water in my home town of Perth in Western Australia doesn't seem to have excessive levels of chlorine as I have always changed out my water in fish tanks with water straight from the tap, and I've never had any noticeable detrimental effects in my system.

Maintenance

Regular checks should be made of your system to ensure everything is running well, a quick scan to check for any leaks in the system or blockages which may have occurred, checking water levels in the fish tank and drain tank if you have one on your system. Also check for any insect attacks on plants.

Check the fish most days when you feed them, ensuring that they are feeding well. If the fish are off their feed it could be an indication of poor water quality.

In a system which has multiple grow beds it's a good idea to clean out a grow bed once you have harvested a crop, to help remove any roots or other gunk which may have built up in the gravel, and thus reduce chances of water blockages. This can easily be done with a garden fork and a nail rake and leaf rake. To get to the gravel you will need to remove the irrigation grid. This offers the opportunity to clean the piping out at the same time. This is where it is useful not to have glued the irrigation grid pipes together. Now in one easy motion you can harvest a bed, take the irrigation grid off and clean it, and rake the gravel with the nail rake to remove any roots dropped leaves etc.

If you have just grown a crop with a large invasive root system, or maybe a crop which had been left in for a long time, it's an idea to carefully use a garden fork to dig through the gravel removing larger and/or deeper roots from the grow bed. If you have any doubts about digging a sharp pronged instrument into your grow bed then don't do it, and I don't advise using a fork if you have wooden grow beds with a plastic or rubber liner as these are easily punctured and not easy to fix when you have to dig out all of the growing medium to replace a leaking liner. If in doubt use your hands to dig into the gravel and remove any remove any excess roots.

Other general maintenance which may be required if you have an ebb and flow system is checking the tethers on the pump float switches, being sure that they are secure and move freely, I will include further details about float switches later in the design section.

With a multi-bed ebb and flow system, each bed has its valve directly above the bed to control the amount of flow going to individual beds. If you have children or friends around be careful that someone doesn't change your carefully set valves. If at all possible when designing and installing your system try and find valves that have a removable handle, then the temptation of twisting the valve won't even be there. Better still, install the valves up high where smaller hands can’t reach them.

Another aspect of regular maintenance is to check for build-up of detritus including uneaten food, faecal matter, algae and other dead plant matter and micro-organisms in the bottom of the fish tanks. This detritus consists of This may or may not be a problem in your system depending on what type of fish tank you have. Many purpose built aquaculture tanks have conical bottoms so that all detritus falls into the centre sump at the base of the conical base, where it is pumped through the system. Cleaning of systems is explained in more detail in a later chapter.

Chapter

3

System Designs

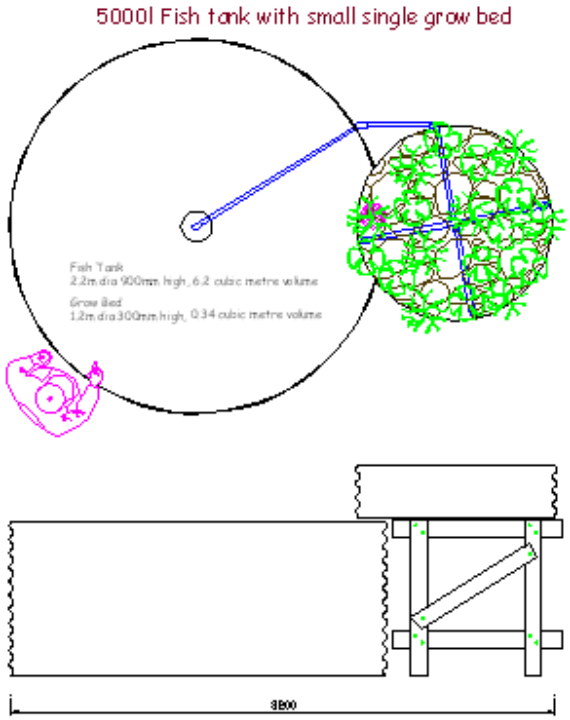
A selection of different system designs, many including comprehensive parts lists.

System designs, and type and amount of fish you can grow in an aquaponic system depends on what you want from your system, and how your system is set up. As I mentioned earlier, when using grow beds filled with media, as opposed to other methods such as NFT guttering and floating raft systems, there are two basic types of system. Continuous flow, which generally requires only one pump, where the water is pumped up from the fish tank, and irrigated through the gravel beds, draining back into the fish tank through gravity. Ebb and flow systems, or as they are also known, flood and drain, works on the principle of pumping water out of the fish tank, flooding the grow beds to just below the surface of the gravel before the pump switches off, the water then drains from all of the beds down into a sump tank, and the water is then pumped back into the fish tank. Flood and drain systems can also be designed to use only one pump, so long as the grow beds are higher then the fish tank to allow the water to flow back into the fish tank by gravity.

The practice of flooding and draining the beds has been shown to be the best method through trials when compared with the continuous flow systems. Continuous flow systems can build up roots and algae in the gravel and, the water flows in certain places and certain directions possibly causing areas of your grow bed to remain dry, and making the plants suffer, while other areas may be flooded. I've experienced this first hand with my continuous flow system, especially when I've left plants in the grow bed too long and the excessive root systems have caused the water to not be able to penetrate into the gravel.

I guess the specific design you will choose for your own system is going to be a personal choice, based on available area and costs.

Continuous Flow Systems


5000l Fish tank with small single grow bed
Fish Tank
2.2m dia 900mm high, 6.2 cubic metre volume
Grow Bed
1.2m dia 300mm high, 0.34 cubic metre volume
3800

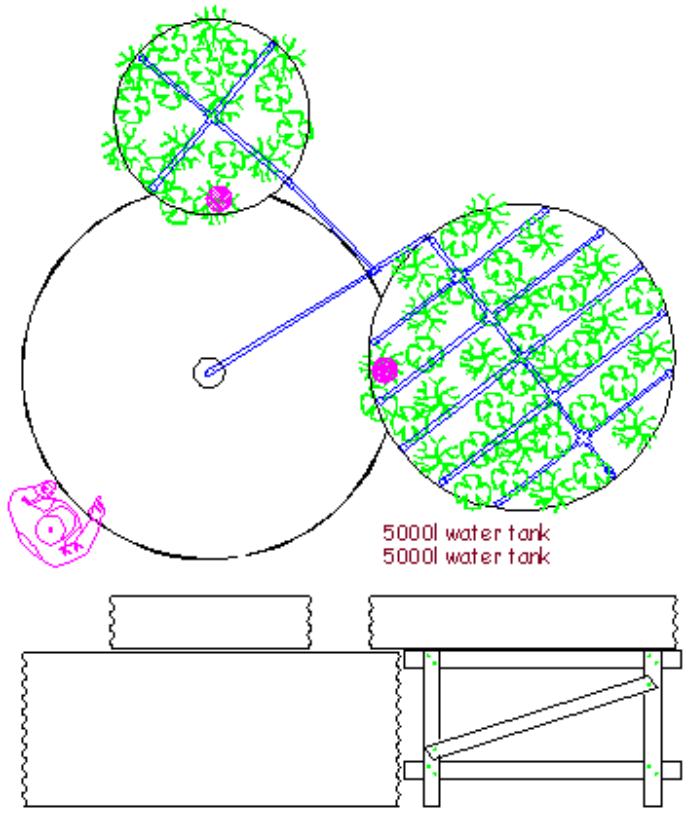
Ideal for home use, this comes in many design variations to suit the site you had planned for your aquaponic system. The flexibility relates directly to what you want to do with it and how much of a stocking density you want in your tank.

My Simple system is designed as in figure 18, I have about 50 fish, ranging from 50mm up to 400mm as well as a few marron, however I have pushed this system beyond it's capabilities. Fifty fish was fine when they were only small but as they have grown, the small grow bed isn't enough to deal with the ever increasing levels of nutrient in the water. Ultimately I shouldn't have so many fish in the system with only such a small grow bed, it just can't keep up. Ideally this system with the one small grow bed would be more suited to a stocking density of around twenty five mature fish.

Figure 18. Simple single bed design

Every few months the water begins to become a little cloudy, building up the levels of nutrient in the water, and thus the algae, causing me to pump out 1/3 of the water into the garden and replace it with fresh water. Ultimately I shouldn't have so many fish in the system with only such a small grow bed, it just can't keep up.

Another problem I have in this small system is that when I want to harvest the plants in the grow bed, I can't harvest all of the plants at the one time. If I did, then there would be no plants to use the nutrients in the water and any problems of high nutrient levels would be increased many fold. It's just a case of getting the balance right. So I have to try and harvest a half, or quarter of the plants at a time being sure that there are always enough plants left growing to keep extracting the nutrients from the water. This isn't too much of a problem in winter, as the water temperature is cooler, the fish slow down and don't eat as much, this offers a chance to harvest the whole bed and give it a bit of a clean out before planting a new crop.



With the addition of another small or larger bed some of the problems are solved, I can harvest most, if not all of a bed of it's plants without to much of an adverse effect on the system as there is still another bed to take care of the filtration. However, with much lower fish concentrations in the tank, the one small bed would be quite capable of sustaining itself indefinitely without the water changes, although my garden would probably miss it's intermittent watering with the nutrient rich water from the system.

This system could also be well adapted to a smaller fish tank, personally I see the ultimate system for a small single bed set up, to be a tank of about 1.8 meter diameter, with a grow bed of around 1.2 meter diameter, and a fish stocking density of around 20 fish. This lower fish stocking density allows for them to grow to maturity in the system, without becoming too heavily stocked.

Figure 19. An additional bed makes a vast improvement to this design

However, as with the larger tank and heavier stocking, you will still need to only harvest half your grow bed of plants at the one time, as you can't leave the grow bed empty at any time, or you wont have sufficient filtration of nutrients from the water.

The system can be adapted to whatever sized tank and grow bed you happen to have. When building a system to a very low budget, the grow beds might be made of recycled wood and lined with plastic, or modified rubbish bins, feed bins, or water troughs. A system can be built out of so many different things, it's just a case of using your imagination if you're stuck to a tight budget.

Ebb and flow, or flood and drain systems are a more efficient way of doing things. This type of system relies on a reasonably consistent water level in the system, so must be under some sort of cover to be sure that the system won't fill with rain. If a flood and drain system is allowed to catch rain water then it will quickly overflow as all of the beds collect water and drain into the drain tank that pumps the water back into the fish tank.

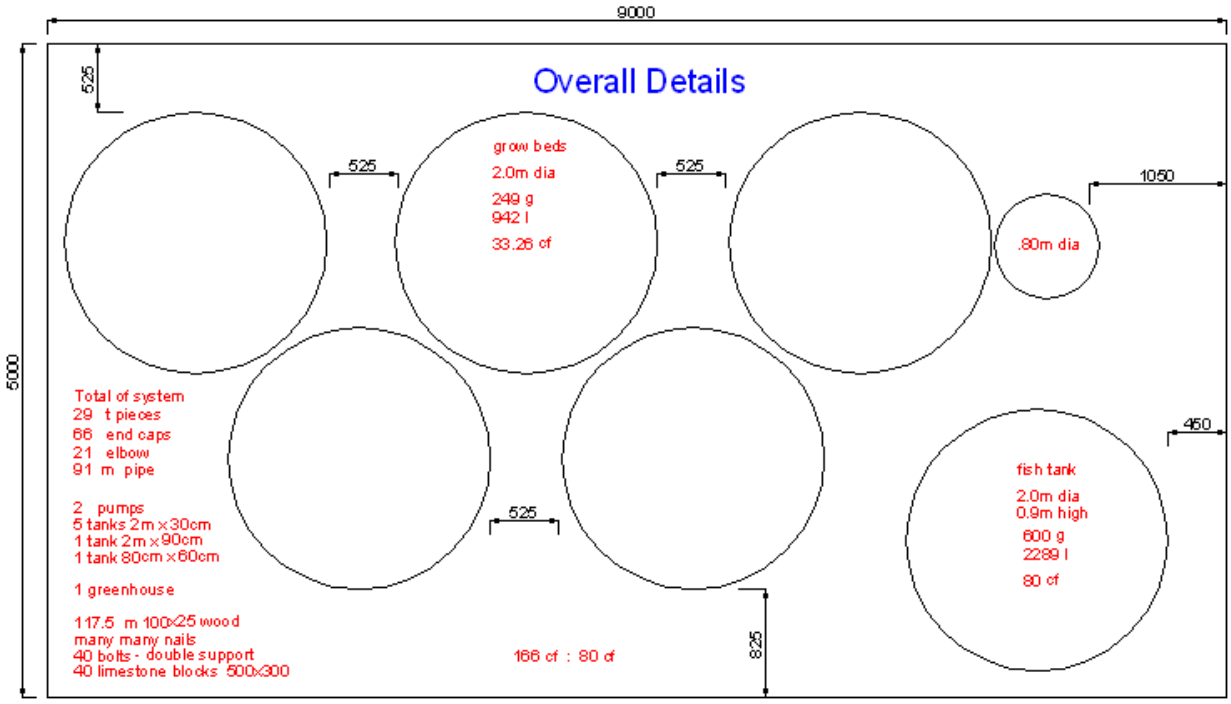


Figure 20. Overall layout of a node, including parts list.

The plan above is for a single node aquaponic system, housed in an area of 9 metres by 5 metres with 5 grow beds and one fish tank, all 2m in diameter. How you house this system might depend on your climate, in temperate areas a clear roof over the top may be sufficient, where as in cooler climates you will probably want an enclosed area to allow for more successful growing in the cooler months. An enclosed system may also be required if you are subject to high winds.

This system has been designed based around corrugated iron tanks and grow beds, and with a grow bed to fish tank volume ratio of over 2:1, quite high stocking densities would be possible.

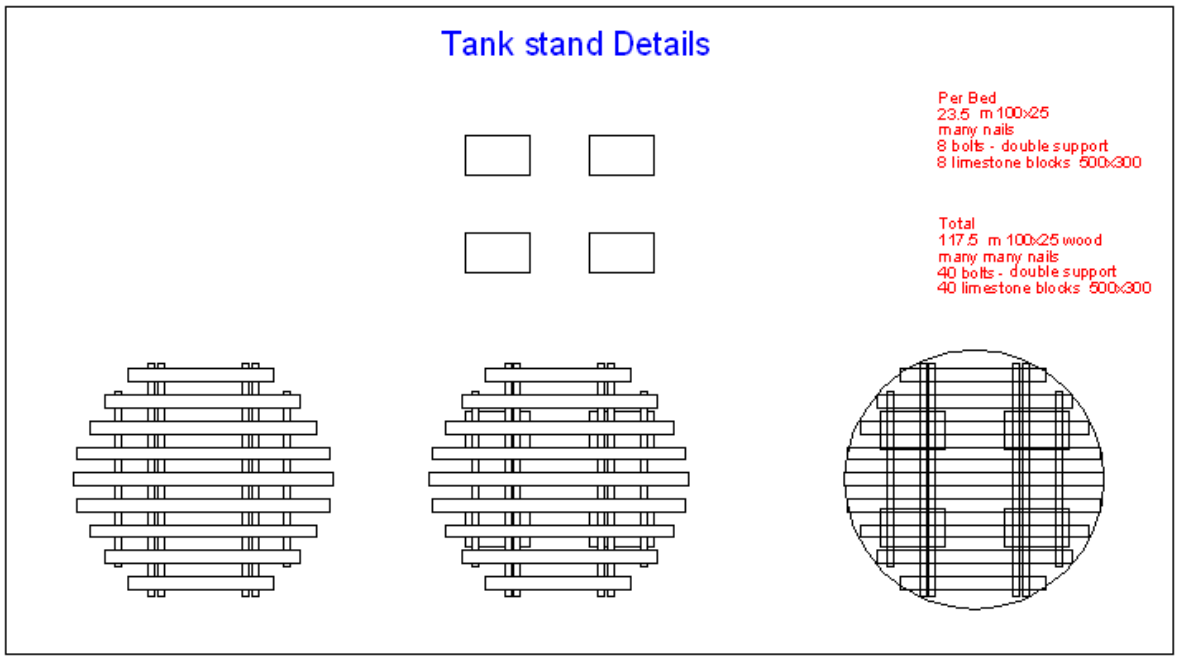


Figure 21. Grow bed detail, including parts list.

Stands for the grow bed are easy to construct They are made in two sections, firstly, a timber frame for supporting the grow bed, which rests on 4 pylons made from limestone blocks, these could also be made from prefabricated concrete type building blocks.

The supporting blocks need to be placed out on the ground to suit the dimensions of your frames, or support joists, form 4 pylons or legs for the bed support frame to sit on.

Each central supporting joist of the stand is made from two pieces of 100 x 25 treated pine, jarrah or similar wood, solidly bolted together to provide extra strength for supporting the grow bed. The main support joists could also be a larger timber beam, something along the lines of 100 x 50 or 100 x 75 would make a perfect joist. In this design I used what was readily available for the construction and I had lots of cheap 100 x 25 treated pine which was cheap to buy.

The surface battens are made from the same 100 x 25 mm timber, spaced at 100mm spacings, nailed down to the joists with nails punched in with a nail punch to be sure the nail heads don't rub against the base of the grow bed.

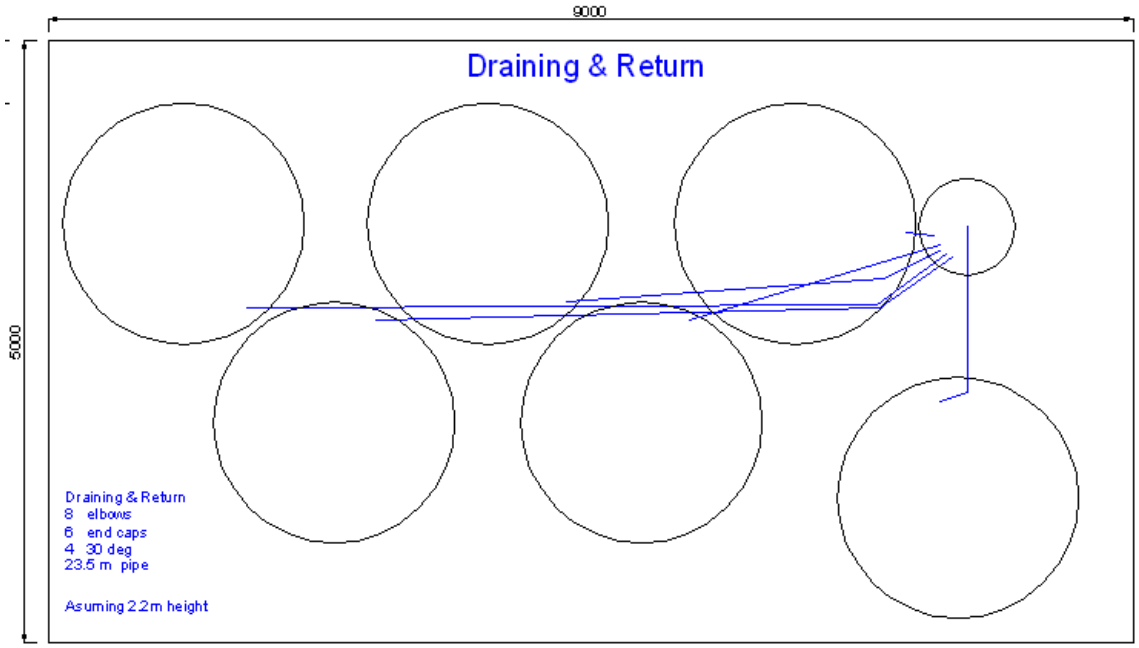


Figure 22. Draining plan, including parts list.

Thought must be given to the lay out and orientation of the grow bed supports so as to allow for the drain pipes to reach the sump tank as uninhibited as possible, with as few angle and joiners as possible. This can be tricky in it's self to design your drain pipe layout depending of course on the system you are trying to install.. The pipes have to be angled downwards to allow the water to drain from the pipes into the sump tank and depending on the floor that your system is sitting on, you may decide to dig the sump tank into the ground to allow some more fall on the pipes coming from the furthest bed.

Where the drain pipes enter into the sump tank the drain pipes have end caps which have holes drilled into them, it's a good idea to have many end caps with various number of holes drilled into each cap, this is to control the rate at which the beds drain, and thus the cycle time of your ebb and flow system. It is handy to have a few different ones because when you want to adjust the pump cycle timing it's just a simple case of swapping end caps for a cap with more or less holes to speed up or slow the flow, and thus the length of time between pumping cycles.

The cycles can also be controlled without using end caps on the drain, and instead using stand pipes in the grow bed to control the rate at which the water drains from the grow beds. I have dealt with this method in more detail later in the book..

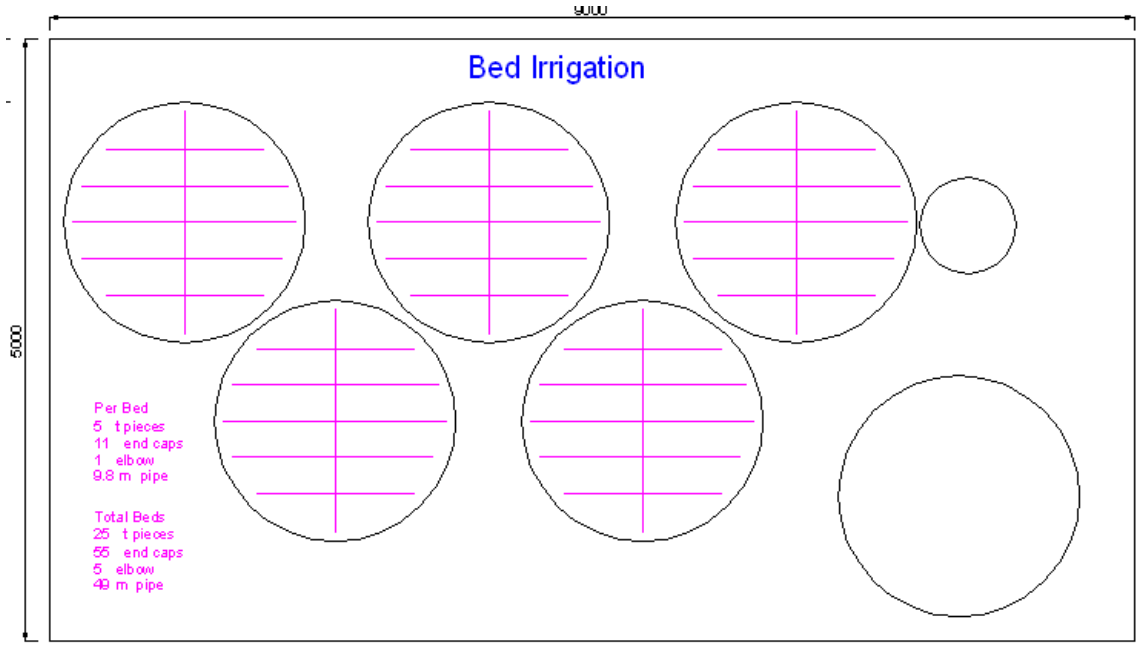


Figure 23. Bed irrigation layout, including parts list.

The fittings for the bed irrigation grid don't need to be glued, in fact it's best if you don't glue them together, as between crops or at least periodically the grid pipes should be pulled apart and cleaned. Algae can easily build up in the drain holes, as well as bits of fish muck out of the water, so these will need to be flushed out. I pull the pipes apart and use a garden hose with a hand piece on the end so that I can adjust it to a hard jet of water, this easily blasts off any algal build up in the pipes and holes.

The spacings of the off takes in this design are standardized at 30cm or 1 foot spacings with holes drilled in the pipes at a spacing of around 20cm between holes. Each bed will require 5 +-pieces, 11 end caps, and 1 elbow and 10m of 20mm poly pipe. The inlet elbow for the grow bed has a piece of poly pipe approximately 50mm high with an adjustable ball valve above the bed, the ball valve on the inlet to each grow bed allows you to adjust the flow rate entering each bed individually.

Again, further details and diagrams can be found in later chapters.

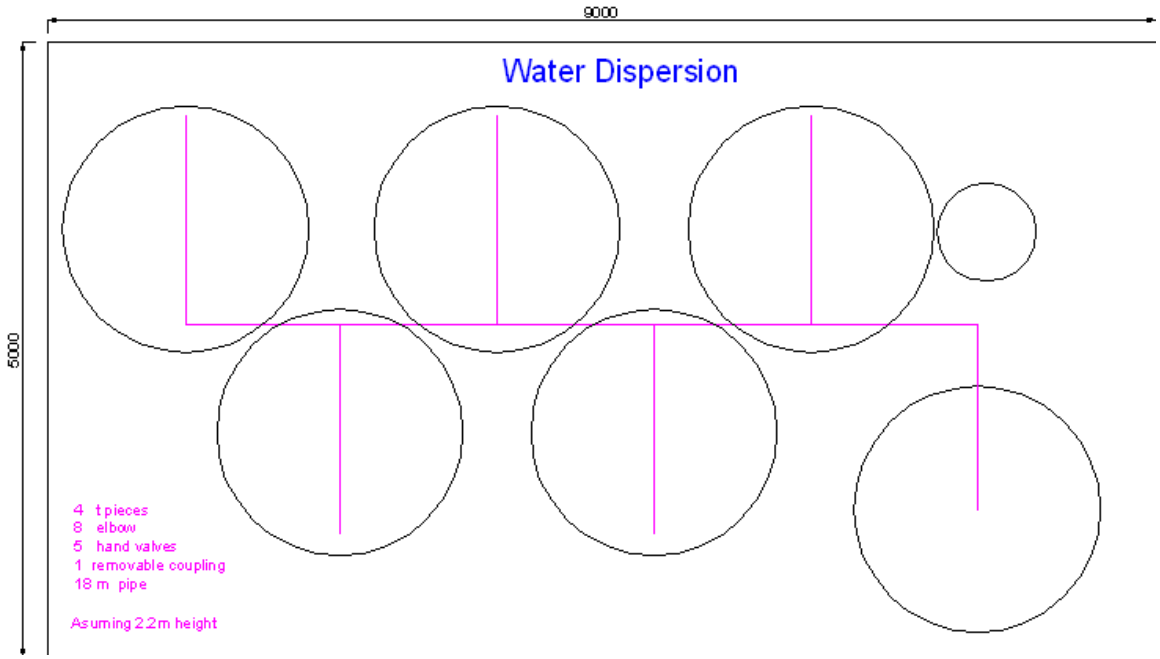


Figure 24. Water dispersion to beds, including parts list.

The individual beds are irrigated via an overhead pipe system. Above the pump it's a good idea to install a non return valve in the pipe line, this will give you longer pump life as pumps prefer to start under load, about 30-40cm above the water level of the fish tank, I have the non return valve and directly above this I install a T-piece with a ball valve on the off take of the T. This off take with the valve allows you to attach a hose and pump water out of the system rather than to the beds which is handy if you need to do a bit of a water change. If you prefer you can place the T-piece and ball valve just above the return pump.

This basic design can be modified to your available space or financial situation. In a later chapter I deal in some detail with a very similar design with four grow beds.

One or two grow beds could be removed, diameters of the tank and grow beds can be increased or decreased and layout can be rearranged to fit into the available space which you may have.

Chapter

4

The Fish

Fish are the main engine of your aquaponic system, converting fish food into food for your plants, as well as fun, nice to look at, and generally damn fine to eat.

The type and amount of fish you can grow in an aquaponic system depends entirely on what you want from your system, and how your system is set up…

Your fish choice might be a simple as gold fish or koi, these will live very well in an aquaponic system and I know of a few people who grow out Koi to mature sizes for profit in their system, that is, buy a couple of hundred small coy cheaply, keep them for as long as you require, and then sell the larger fish at a profit to the ornamental fish trade.. In fact this method can be used for any ornamental fish as mature specimens are always worth proportionately more than juveniles. Meanwhile you have been able to 'use' the fishes services, as the food for your plants growing in your beds.

Of course fish choice may depend on the climate, unless you plan on heating and/or a green house which is going to increase the costs of your set up. If you live in the warmer areas you choices will be far more flexible.

For aquaculture purposes the ideal situation is evenly sized fish. Fish of equal size generally have equal chances at getting feed, where as in a tank of varied size fish, smaller fish may miss out in the competition for food and the size difference becomes greater over time. In many intensive recirculating systems, fish are sized as often as every 8-10 days, promoting even sizes and even growth rates facilitating easier harvesting procedures and a more marketable uniform product.

However for a hobby system that is set up for aesthetic purposes, personal vegetables and herbs, and the occasional fish dinner, I have found that size variation is useful, rather than detrimental. Larger fish generally only eat larger pieces of food leaving small morsels to fall to the bottom of the tank, and become a problem to be removed from the tank, and/or pumped through the system. With various sized fish in the tank smaller fish tend to clean up the smaller scraps, thus making feeding more economic as there is less waste.

I often watch my larger fish chew the feed pellets, as small particles drop from their mouths the smaller fish swoop in eating them up, it adds to the aesthetics of the tank to have a variety of fish sizes rather than all the same sized fish. But, as I stated earlier, this is only if your system is for more your hobby or aesthetic purposes.

For any commercial venture where fish will be harvested when they reach marketable size it becomes a nightmare if there is a large variation in fish size, as the fish have to all be graded and sorted at harvest time.

Polycultures are mixtures of different species in the one environment. A polyculture may consist of two or more varieties of finfish, or it could be a combination of finfish and a crustacean species. A Polyculture is a very useful idea, especially if your system is just a hobby set up purely for pleasure, as this creates variety and helps keep things more balanced, as with an aquarium set up in a house, variety of fish sizes and species adds to the dramatic effect. An aquarium filled with just one type of fish, all the same size wouldn't capture your attention, where as one with a small school of one variety, one or two specimens other varieties of fish, as well as maybe a catfish or two and perhaps a couple of crustaceans, looks more natural and pleasing to the eye, as well as being biologically more balanced.

Stocking Densities

Stocking densities depend on a number of factors, as a general rule, the higher the stocking rate of your aquaponic system, the more work is involved in keeping the water quality at an acceptable standard. Aquaponic systems can be as heavily stocked as any other type of intensive recirculating aquaculture system, with the added bonus that you have your vegetative crop as well. Tilapia have successfully been grown at densities of ½ -3/4 lb (200-340g) per gallon (3.8 litre), this equates to a tank the size of mine 5000L (1300 gallon) in the simple continuous flow design, of being able to produce 300 - 440kg of fish, that's a lot of fish considering that many species can be grown out to market size in around 18 months, so in 12-18 months you could be looking at a harvest of 300-400 kg.

However such high stocking densities walk a fine line and a power outage only for a very short period of time can cause total loss of stock as there is no buffer, no room for any leeway.. It's much safer to grow your fish at slightly lower stocking levels where the system is more able to withstand fluctuations in water quality.

If you want to have high stocking densities you must have the filtration required to keep the water quality at it's peak. Grow bed to fish tank volume ratio of around 2:1 is sufficient filtration to support stocking densities of around 6kg per 100 litres of fish tank. This is allowing for mature fish, o when stocking your system with fingerlings you have to make an allowance for the final growth of the fish. A typical example may be a 2000 litre tank in a system with a grow bed ratio of 2:1 can be stocked with about 120kg of fish at maximum production. Assuming you might harvest your fish at around 750g each, this would allow you to have about 160 fish. Therefore when buying fingerlings for your system you might reasonably assume that 180 fish would be reasonable allowing for a few mortalities.

In my aquaponic system, a hobby one for aesthetic purposes the fish get a varied diet, they have a standard diet of sinking fish pellets but I supplement that with many other things. they get prawns, mussels, meat, a few times after eating a meal I have walked up to the tank and scraped my scraps from the plate into the tank, of course I don't do this too often, but variety is certainly a good thing in the diet of the fish. Such things as adding prawns to the fishes diet means that there are many other benefits which may not be quite so noticeable, the prawn shells add calcium to the system, there are other nutrients and minerals which are in the prawn head and gut which may not normally get into the system..

However, you must be vigilant what's going into your system because what goes in generally stays in the system, and also effects everything in the system.

Never feed too much, excess feed builds up in the system if it's not flushed through the beds, or out of the system altogether it can cause toxic build-ups. It can also add to the algae problems and decreased dissolved oxygen in the water. Fish only need between 1 and 4% of their body weight in feed, but if you can't figure that out then just feed them some food slowly and observe your fish, when they begin to slow their feeding activity it's a good idea to take that as an indication to stop. If in doubt don't feed, if water quality has dropped and algae build up is becoming a problem, you want to try and lower the feed going into the system for a little while, drop the feed rate right down or cut it altogether for 24-48 hours, this will not harm the fish in any way, they will be fine without feeding for 3-4 days, which is handy, as it means you can go away for a few days without worrying about feeding, unlike some other animals.

Automated feeders are also available in many shapes and sizes. As a general rule they deposit a pre-measured amount of feed at a predetermined time, and can be set by the day or by the hour, however, if you are going to be away from your system for any length of time, it's always a good idea to get someone to feed for you and have a quick check of the system while they are at it.. Automated feeders are available from most aquarium suppliers.

Of course what you feed, relates to what fish or crustaceans you have in your system There are many commercial feeds available, and it's best to try and get the cleanest feeds available, organic if possible. It's probably best to consult either a feed manufacturer or fish supplier with regards the best feed for your specific fish, they will be able to advise you which feeds are best suited to your particular needs.

Perhaps you would like to try making your own feed, worms make a great fish food for most species of fish and it's easy to breed worms in a worm farm. In summer time I hang a mozzie zapper light above the fish tank, in the suburb where I live we are blessed with many lakes and swamps in the area, and as such have a diverse and prolific insect population in the area, I liken the bug zapper to an automatic feeder, moths and other insects fly in from miles around to become fish food, self serve style.

Insect larvae make a high protein valuable fish food. Fly blown meat scraps suspended above your fish tank can provide a staggered, constant source of maggots for a long period of time, as the maggots mature they drop into the water. There are stories of people collecting road kill and suspending it above the tank or pond, however this is going a bit too far for me. I'd rather just buy my feed personally, though I do have a worm farm and I like to give my fish a worm meal treat now and then. You can tell they much prefer the worms to pellet feed, not surprisingly.

I often feed the fish snails from the garden which they relish, I throw them on the ground first cracking the shells, or crush them a little under foot before feeding it to the fish, otherwise they float because of air trapped in their shells, it also makes it easier for the fish to eat them with a crushed shell, and slugs, I also have giant slugs at my house, they can be up to 100 – 130mm long and the fish fight over these tasty morsels whenever I throw them in.. Of course I know I can safely feed snails and slugs from my garden to the fish because my garden is organic. I use no sprays, artificial fertilizers, or snail pellets. If there is a risk of contamination then you should never try this. It's probably not a good idea to feed too many snails into the system unless you remove their shells, as the shells will build up in the system and cause blockages.

Basically, if in doubt, just buy your fish pellets from an aquarium or fish supplier, they generally sell them in moderate quantities up to at least 5 litre bags, they are expensive, but readily available, and they can advise you as to the correct sized pellets for the average size of your fish. It's worth checking stock feed suppliers in your local area, as buying in bulk can reduce feed costs considerably.

Different species of fish have different feed conversion ratios. A feed conversion ratio, is the amount of weight a fish can be expected to gain for the weight of feed consumed. If you like it could be defined as the fishes efficiency of converting feed into body mass, and the better the food conversion ratio, the more growth you'll get for less feed.

Fin Fish Species

Barramundi

Figure 25. A fish for all occasions……

Barramundi (Lates calcarifer), originates from the warm waters of the South-East Asian region, including northern Australia. Barra are highly viable in an aquaponic system.

In some areas barramundi are known as Asian sea bass and they have been successfully farmed in Thailand for many years. In the wild, they can grow to 180 cm total length (up to 60 kg) but farmed fish are usually sold at plate size (500 g) or up to around 3 kg for fillets.

At the time of writing this there is a company in New South Wales, breeding and growing out Barramundi in what is probably the only commercial aquaponic venture in Australia, Tailor Made fish farms produce barramundi and fresh salad greens and herbs for the commercial and domestic market. Presently they are producing about 600kg per week of barramundi mainly for food, with some for aquarium fish sales as well.

Barramundi are also being grown in a number of places around Australia, in a variety of ways, cage culture, ponds, and intensive recirculating systems are all being used for growing out barramundi. They prefer a temperature range of between 24 and 28 degrees C, and food conversion ratios are fairly good at around 1.7:1.

Barramundi can be susceptible to some diseases when grown in intensive tank cultures such as aquaponics, diseases caused by bacteria are the most common cause of death in farmed Barramundi so maintaining water quality and hygienic practices are important. Also crucial in the choice of Barramundi for your system, as with Tilapia is that they are tropical and as such require higher water temperatures. If you live in cooler areas then you will have to look at supplemental heating and/or an efficient greenhouse structure. All things considered, barramundi fingerlings a fairly readily available, as well as live mature specimens, barramundi would make an excellent choice for either a hobby aquaponics or a commercial venture.

Barramundi are commonly grown out to size in commercial aquaculture systems in the cooler areas of Australia without any supplemental heating. This is done by buying advanced fingerlings at the start of spring as soon as the water has heated up to around 22-24 degrees, they are then fed intensively over summer and into autumn till they reach the required plate size of around 500-700g, then they are harvested. As the water temperature drops as the weather is cooling, the tanks are restocked with trout fingerlings to grow out to size over winter. Two fish crops per year is a rather exceptional harvest rate and requires a well managed system, but this shows what can be done with a little thought and planning.

Goldfish And Koi

Figure 26 The goldfish and the Koi, the most commonly known fish around the world today.

I figured it easier to group these two together under the one heading because, hey, if your going to try either of these, chances are it will be a specific ornamental fish you already like, and know a bit about, or you'll be trying the bomb proof method of going for goldfish… If you're looking at starting an aquaponics system for the first time and you're wondering which fish will be easiest for a first attempt, that is harder to kill by any mistakes which may be made along the way, then goldfish are the way to go.

Firstly they are one of the cheapest fish you can buy from any fish shop especially if you are buying small ones and buying large quantities. They can survive an incredibly diverse rang of conditions, personally I have had goldfish survive water temperature swings between seasons from about 8 degree C up to 25degree C. I've seen ponds with only a couple of inches of water left in them after years of neglect yet miraculously there are still a couple of goldfish alive, in amongst all the muck..

As well as surviving a diverse range of temperatures and water quality, they eat a very diverse diet, omnivores in the true sense of the word, they can survive in ponds in low densities without any supplemental feeding.. I tried to grow duckweed in some large containers with one goldfish in each container for mosquito control, now duck weed is as it's name implies, a weed and very prolific at that, yet my individual goldfish managed to chew

through all of the duck weed within a couple of days the surface of the water had changed from 80% covered in duck weed, to zip, not one plant left..

Goldfish can be bought very cheaply from pet stores, and if you're not too fussy about having very pretty brightly coloured fish then you can buy what are often called feeder fish. Feeder fish are basically comets and fantails without any colour to them, they are a bronzy brown colour and not so readily saleable as the brightly coloured fish, and as such they are destined to become food for other fish. One attractive aspect of the feeder fish apart from their price is that they often change colour, and your boring brown fish may develop some striking colouring over time.

Koi require slightly better water quality than their closely related goldfish, and are a little more expensive in the initial outlay. Koi are a highly prized fish and as such worth more at an advanced stage. Koi are highly prized by collectors and some specimens can fetch hundreds of dollars, even thousands for mature prime collectors specimens. However it would be rare for a novice to breed and grow a fish of such monetary value There is a great deal of information on the culture of Koi available, and I suggest that if Koi is going to be your choice of fish then you study the great deal of information available.

. Figure 27. Black bream from my tank.

Ahhhh, the black bream (Acanthopagrus butcheri), fondly known in Australia, especially the southern half as an excellent angling fish, as well as a superb eating fish. Before setting up my original system I studied the black bream trying to glean any information I could find, as they seemed ideal for aquaponics as far as I was concerned..

However, the information I found was not so conclusive and it seemed like my high hopes for the black bream in aquaponics wasn't founded in facts, but rather fanciful thoughts of much loved fishing trips..

All of my research into black bream said that they did not perform well in fresh water, it was suggested that stocking of inland farmers dams would be a total failure, and that they should be grown in salt-affected dams or in ocean or estuarine waters, but I stocked a number of black bream into my aquaponic system anyway, as I was never one for conformity anyway. The fish have survived although each winter as the water cools they become susceptible to diseases like white spot, and although this hasn't directly killed and of the bream I have in the tank; it affects their feeding and growth rates adversely. When a fish becomes diseased it can be attacked by the other fish and I've found a couple of half eaten carcasses floating on the surface.

Black bream are fairly adaptable to a variety of water conditions, from sea water to fresh water, and in some circumstances can be adapted from sea water to fresh water very quickly with no obvious ill effect I have acclimatized bream from sea water to fresh water in less than one hour quite successfully, however, I wouldn't recommend taking bream from natural surroundings to incorporate in your aquaponic system as there is a very real chance of infecting the system with diseases and pathogens which can effect other fish you may have. Also Black bream are less tolerant when taken from their natural surroundings and placed into an aquaponic system, or any unnatural system. In the wild they may have been carrying a virus, bacteria or pathogen, yet be relatively unaffected by it. However once placed into an intensive fresh water environment, not only is the likelihood of infecting any other fish in there, but there is a much higher risk that the fish will become adversely effected by the problem..

One of the main problems with the black bream is their slow growth rate, this won't be a problem if you have your aquaponic system purely for pleasure, and they are a very attractive fish with their large lateral fins. If you want to see a decent amount of growth or you want to try and set up a more commercial venture, then there are far better species to grow than black bream.

Silver Perch

Figure 28. The silver Perch, an excellent choice for an aquaponic system.

Silver perch (Bidyanus bidyanus) are a native to the Murray Darling basin in eastern Australia. Silver perch have often been called the sleeping giant of aquaculture, and they are a fish which is ideal for aquaponics. Silver Perch show great prospects for aquaculture not only in Australia but also the world. Recent trials have found that they enjoy a reasonably low protein diet compared with most carnivorous fish, with maximum growth rate coming from feed of around 35% protein as opposed to 50% protein normally recommended for other farmed carnivorous fish. They have a very low mortality rate, prefer a temperature range between 18 and 30 C, and when intensively farmed and fed optimum diets they can easily reach 500g in 10-12 months

Silver perch can tolerate relatively poor water quality, with low levels of dissolved oxygen, and salinity levels up to 10ppt (parts per thousand). They are omnivorous and have a special tendency toward fresh water shrimp and crayfish, so a little thought needs to go into your choices, here, there's no sense mixing silver perch and yabbies in the same tank, not unless the yabbies are meant as food for the silver perch. I found this out the hard way. They also prey on Marron in clear water, so in a polyculture careful thought must be given to selected species. I have grown them very successfully in a polyculture tank mixed with black bream, and Murray cod though this was only at a very low stocking density. An interesting feature I

noticed in this polyculture tank was that the silver perch became territorial and a little aggressive toward the other silver perch in the tank, and yet not aggressive toward the black bream.

Research of the potential for Silver Perch only began maybe 20 years ago, and there is still much work to be done, in the past poor aquaculture practices lead to the fish earning a bad name, however with a pre harvest purging the fish has high quality meat with a low bone content, so the future looks good for the Silver Perch given more research. Post harvest purging is simple, the idea being that the diet of pellet feed can taint the fishes flesh flavour. Fish are placed in a clean tank and fed no feed for a few days before their final harvest, this allows all the feed to leave their stomach and in this way there is no possibility of adverse flavours affecting the flesh from the gut of the harvested fish.

In an aquaponic system at a hobby level they are a fantastic fish growing very quickly, while accepting of poor water quality on occasion without ill effect. Possibilities for commercial production in intensive recirculating systems such as aquaponic systems also seems to have great prospects, though in some states the fish are well regulated to reduce the risk of them becoming established in natural waterways, destroying local native species.

Silver perch quickly became my choice of fish for aquaponics. Firstly because of their growth rate, within 18 months of stocking a mixture of black bream and silver perch fingerlings into my system I had mature 1kg healthy silver perch about 350mm in length, while the black bream were only around 150mm in length.

Silver perch fingerlings are widely available over most of Australia, in Western Australia alone there were five fingerling suppliers listed in the yellow pages, more than any other fish species. They are very resistant to diseases. In the systems I have had with mixed species of silver perch and black bream, the silver perch have never had disease problems even though the black bream will be quite visibly diseased with white spot, the silver perch are clean and healthy.

Murray Cod

Figure 29. Murray cod, the mightiest of Australian fresh water fish.

Murray cod (Maccullochella peeli peeli) is the largest Australian freshwater fish, and an impressive little beast it is too. Before human degradation of habitat, pollution and over fishing became an issue during the last century, Murray cod to over 100kg could be found in the wild, with an estimated age of 80 years. Nowadays only very few specimens up to 40 kg are caught in the wild. Previously they were considered unsuitable for growing in intensive recirculating systems, mainly because of their aggressive territorial nature, however more recently it's been found that when reared in tanks at high densities, it reduces the chances of individuals becoming territorial, thus losing their aggressiveness.

Murray cod enjoy a varied diet of Yabbies, shrimp, freshwater mussels, other fish, frogs, tortoises and small birds, basically anything which gets within reach of it's enormous mouth. It's well known for it's predisposition for lurking in dark hidden places like hollow logs and under tree roots, whenever anything comes within striking distance the Murray cod lunges forward with it's enormous mouth gaping open, engulfing it's pray before slinking back to it's hiding place.

Murray cod prefer reasonable water quality, and a temperature of around 24-25° C, though they are hardy and have a strong tolerance to temporary fluctuations in water quality, a highly recommended species for aquaponics. Although Murray cod hold such great prospects for use in recirculating aquaculture systems, fingerling supplies can be difficult to find, especially in states where the fish are not native. In Western Australia I have not been able to find a supplier of fingerlings and there are restrictions on bringing them in from different states. This means I have only been able to try a few which I have paid very high prices for, as they are aimed at the aquarium specimen buyer. Work is being done in the eastern states on experimenting with Murray cod in Aquaponic systems, and if they are available where you live it would be well worth growing them

Figure 30. Tilapia, said to be the fish eaten by Jesus with the loaves of bread.

Tilapia are not recommended for growing in Australia. They are the species of choice for a large percentage of aquaponics ventures in the U.S, and many other parts of the world. The Tilapia, a member of the Cichlid family, are an incredibly hardy, prolific, fast growing fish, which requires water temperatures ranging preferably between 24-28 C (76 to 84 F).

They tolerate a wide range of environments, are resistant to many common fish diseases, and are relatively easy to reproduce in captivity. This ease of reproduction actually represents one of the principal problems optimising yields in tilapia culture, the fish breeds TOO READILY. Energy is diverted from growth into the production of young. The most effective solution to this problem is to grow only one sex, preferably males, as they grow faster and to a larger size. There have been numerous technologies developed for this purpose including hybridisation and direct hormonal sex reversal..

Their prevalence toward breeding also means they are a problem in natural waterways and as such are strictly sanctioned in many countries including Australia, where in some warmer areas they have become a serious problem in local water ways, decimating native species.

In an aquaponic environment they perform exceptionally well growing from fingerling to marketable size in 9-18 months depending on conditions. They have a food conversion ratio which is difficult to match at 1:1, for each gram of feed they consume the fish puts on a gram of weight. Tilapia have rakes on their gills which filter out algae which they consume, so they also help to keep algal levels low in a recirculating system. Tilapia can also withstand very low levels of dissolved oxygen in the water, some have even been reported to survive for a couple of hours out of water.

However ideal the fish may be for aquaponic purposes, in Australia fingerlings suppliers are not common, there is no established market for tilapia as an eating fish, apart from maybe in the Asian population. Regulations are so tight on tilapia in Australia, that even to buy one aquarium specimen from an ornamental fish supplier, requires them by law to inform the purchaser of the regulations regarding the species, and get a signature from the purchaser for fish received, to account for each and every fish sold.

Pacu

There are a number of lesser known species that might be tried in an aquaponic system. Pacu, also known as silver dollar fish, have been grown in aquaponic system with great success. Pacu are voracious feeders , which isn't surprising considering they are closely related to the infamous piranha. They are a native of the Amazon and Orinoco rivers in South America.

Figure 31. Pacu are the piranha's brother,.

Pacu have very strong jaws, few teeth, and in their natural environment their diet usually consists of fruits seeds and nuts, feeding in the river systems which are surrounded by the rich lush jungles of the Amazon, many fruits and nuts drop into the water and become a major proportion of the Pacu's varied diet . In an intensive tank system, the Pacu adapt readily to a granular fish feed, and with a large proportion of their natural diet coming from fruits, this could be a useful factor in their choice as an aquaponic species considering that their diet can be heavily supplemented with readily available seasonal or un-saleable fruits, cutting feed costs. However you must always be aware of the origins of what goes into your system, eg, only organic food stuffs so as to be sure not to contaminate either your fish , plants, or bacteria.

The Pacu can survive at very low oxygen levels by extending their lower lip to breathe on the surface level. The Pacu adapt well to poor environmental conditions and can survive long periods of time without food.

Overall a great fish to try in an aquaponic system, and many people in the United States have been growing out Pacu to maturity with great success and very low to nil mortality rate, with a reasonable growth rate.

Trout

Figure 32. Trout, the classic fresh water fish..

Of all fresh water cultured fish, trout are probably the most studied and best documented. World production of the rainbow trout is about 360,000 tonnes a year. They have been cultured since mid 1800's in many ways, using ponds, raceways, tanks, and, more recently, cages. As such, much is understood and documented concerning their nutritional requirements, breeding, and water requirements and there are numerous books on trout breeding and production. Trout, both the rainbow and brown, are cold water fish, they prefer water temperatures between 10 and 22 degrees C, at 25 degree high mortality rates are experienced.

Trout require very high levels of dissolved oxygen in the water compared with most of the fish we have dealt with so far, with minimum DO recommended levels above 5.5 parts per million. They also require optimum water quality for growth and production. Although the rainbow trout is adaptable to a wide range of salinity levels surviving quite well in seawater. In fact trout have been cultured in oceanic cages for some time.

For the purposes of aquaponics however I feel that trout is probably not a wise choice, being a finicky fish which requiring very specific water conditions. If something goes wrong with an aquaponic system, i.e. power failure etc, then you will most likely loose all your fish very quickly as their environment declines, where as other more robust varieties would not be so adversely effected.

However, if you have a penchant for trout, there are many books and papers on trout production which can be studied, and they will grow well in an aquaponic system, though they will need more work than many other fish species, especially if farming at high stocking rates.

Crustaceans

Marron

Marron, (Cherax tenuimanus) are a very large fresh water crayfish, native to the lower south western corner of Australia, the second largest fresh water crayfish in the world second only to the gigantic Tasmanian fresh water crayfish, they fetch a higher price than yabbies or redclaws, and have a flesh recovery rate similar to lobster, with a more subtle flavour…

Figure 33. Marron, the second largest fresh water crayfish in the world

They have been successfully farmed for a number of years now in the south west of W.A. though it's only in more recent years that much research has be carried out to find the best production methods. It's now become a fairly straight forward matter, the breeding and culture of marron, a limiting factor used to be the cost involved for juveniles, though now juveniles are readily available from suppliers and many farmers of marron are breeding their own juveniles.. Oh, and did I mention they get big, in excess of 2 kg.

Ultimately they require large ponds or dams for their culture and grow out, however in the last few years a great deal of research has been carried out into tank culture of marron, as well as research into the breeding of faster growing strains of marron.

Marron are not a burrowing creature like so many other fresh water crustaceans, and there for don't damage ponds and dams like some other species. However they have another method for escaping drought conditions, they walk.. They are incredible escape artists, and I have know people who have kept marron in an aquarium only to find them selves one morning moving all the furniture and searching

through their house because somehow the marron has climbed the straight glass sides of the aquarium, and it's loose somewhere in the house…..!!!!!! with those giant nippers you don't rest until it's found.

Figure 34. The blue marron, a popular species for the aquarium trade.

One unusual aspect of marron is that there is a blue variety, and not just a slight shade of blue, they are pure cobalt blue, incredibly vivid in colour. These are very popular in the aquarium trade as they make a stunning addition to an aquarium or pond.

So far as marron in aquaponics though well there has been very little research, and it's only been in recent years that in-depth research has been carried out into their culture in tanks. However I see great potential in at least a polyculture of marron and fish in an aquaponic system, even if it's only for the purpose of cleaning the bottom of the tank of detritus, as well as the aesthetics of such a noble beast being incorporated into your hobby setup.

There is much information available through the recent research, which has been carried out, and a quick search on the net will answer any questions or queries you may have, see the links later in this manual for further information.

Yabbie

Figure 35. Yabbies, if mixed in the same tanks as fish can tend to be eaten

Yabbies, (Cherax destructor or Cherax albidus in W.A.) or any one of another species of 'yabbie' which are wide spread over most of Australia. There is some confusion as to which species are which, as colours can vary quite dramatically in the same species depending on the yabbies habitat. The Yabbie camouflages it's self through pigments in their shell and in their eyes and these pigments come from the plant matter and food which the Yabbie eats. Cherax destructor can be quite a problem in the eastern states of Australia as it draws it's name from the fact that it's a prolific digger, it digs to escape drought and can dig very deep tunnels, often through clay dam linings and irrigation banks.

My personal experience with growing Yabbies in a polyculture (mixed with fish) is that they make rather expensive fish food, because the fish tend to clean them up in no time. I used to think my yabbies had found some really good hiding places, maybe only coming out late in the night, but when I emptied the whole tank out there wasn't one yabbie. In 6 months 20 yabbies had vanished and there wasn't the slightest trace of them when I cleaned out the tank, not even a shell. I have heard of some people talk of using grates in the water to keep the yabbies and fish separated, but this is quite an effort for a relatively small crustacean. Personally I would recommend the Marron as a more viable option, of course, I'm talking about marron of a reasonable size, as smaller specimens would suffer the same fate as the yabbies.

Yabbies are fast growing, and they can adapt to an extremely wide variation in water quality and water temperature, they are found in hot dry murky pools in Queensland, right through to very cold streams in the highland areas of the more southern states. This could be a useful factor if you are considering a system which will have a high likelihood of suffering from periods of very diverse water quality fluctuations . They would probably do very well when used in a polyculture with some fish such as goldfish, though many of the fish I have mentioned in this manual hunt and eat the yabbies in the wild.

Fish Conclusions

In deciding which fish you are to grow in your own system it will really depend on what you want from your fish. If you have no real interest in growing an eating fish then you can have a tank full of beautiful goldfish. If you have a penchant for natural ecosystems try for a variety of fish, Black bream, Silver perch and Murray cod, with some marron crawling around the bottom of your tank. Perhaps food fish production is more your ideal, then a monoculture is probably your best bet.

Climate will also play a part in your decision. If you live in a suitably warm climate Barramundi should be high on your list of possibilities, while trout will never even enter into the equation.

Chapter

5

The Plants

Plants are your means of filtering the water and extracting the nutrients, as well as being your main harvest from the system, far exceeding the levels of fish you'll get.

When selecting plant or seed varieties, I recommend using heirloom open pollinated varieties of seeds and plants where ever possible. It has been estimated that we have less than one tenth of the vegetable varieties which were available in the early 1900's. Genetic diversity is disappearing. The best method to discover what varieties are going to grow best in your situation is to try many different varieties. When you find the one that works best for you in your particular climate and location, collect your seeds, keep collection the seeds from your best specimens from each crop. As you continually collect seeds from only the best plants you grow, season by season you are going to be growing stronger better adapted plants in each successive year. I also try to collect and/or buy local seeds wherever possible.

If at all possible join the 'seed savers network', they have members all over the country and all over the world so generally you can find someone locally who will have strains of plants which have already adapted and will be ideally suited to your location, although this probably isn't so important with aquaponic growing as growing plants in the ground. When the plants are growing in the ground you will be getting seeds which are particularly well suited to both the climate of your region as well as the typical soil types of your area. You might find it advantageous to join something like 'diggers' seed club, or 'Eden' seeds, they specialise in open pollinated and heirloom varieties.

Even in an aquaponic system, if you buy locally grown seeds, then you know they are adapted to your climate. Which brings me to another point of plant selection. If your system is going to be set up in a green house you might want to try and find plant varieties which are specifically suited to green house growing, i.e. not so prone to fungal infections when growing in humid greenhouses.

There are no hard and fast rules as to what will grow in an aquaponic system. In New Zealand there's a commercial grower of wasabi who has been trialling the use of an aquaponic system to grow the wasabi plants and it's been quite successful.

Root vegetables find it a little difficult if they are trying to grow in the course heavy gravel, but if you are using a finer grade of growing medium then they can be quite successful. Someone from the US has successfully grown

ginger in grow beds, and Chinese water chestnuts are an obvious winner as they love aquatic conditions. I grow healthy crops of garlic in a gravel grow bed. Though personally if your system is for pleasure, and not to be heavily stocked with fish, I prefer to have the water chestnuts in pots directly in the fish tank, sitting on bricks if or in wire cages to raise them up a little so the spears are emerging from the water. Growing directly in the fish tank they add to the aesthetics of the tank, and it frees up space for other plants in the grow bed which prefer dryer growing conditions.

Edible aquatic plants such as the Chinese water chestnut, Taro, water celery and water cress can be grown directly in the tank where they make an attractive addition to your system, or they can also be grown in a separate tank, often used as an additional filter bed for the water before it is returned to fish tank. You must be careful with plants in your fish tank as some species of fish tend to dig plants up to eat the roots and tubers, my taro plant was stripped within a few short weeks and the soil was dug out of the pot so they could get to the stump of the plant, they ate the whole thing.

Fresh water crustaceans can also be a problem when it comes to plants, the marron love to sit in the plant pots and eat bits of decaying matter, and they also climb the plants by shimmying up the stems, you have to be sure that any plants aren't too close to the sides of your tank.

What do you like? Another important factor in choosing which plants are going to grow in your system. If you hate tomatoes then there's certainly no sense in growing them. Many plants easily strike cuttings in the nutrient rich fish water, I've been experimenting with striking cuttings of a number of indoor ornamental plants in the grow beds and all plants I have tried so far have been successful.

If your system is exposed to the elements, then thought will need to be given to what is naturally growing at that time of year. I tend to use numerous packets of different seeds, especially with a new system. I open all of the seed packets and pour them into a bowl, mixing them all together before scattering them all over the beds. Normally the seeds tend to naturally drop into gaps between the gravel particles, though if the seeds tend to be sitting on the surface of the gravel a quick squirt of water onto the surface of the bed should drop the seed down into the gravel.

Last but not least. Experiment, experiment, experiment.

Figure 36. Green leafy herbs and vegetables thrive in the nutrient rich fish water.

Green leafy vegetables and herbs are the most successful plants to grow in an aquaponic system, due to the very nature of the system. As explained earlier, Nitrogen is the element that is most widely available as the bacteria convert the ammonia into nitrites and nitrates, and lots of nitrogen makes green leafy plants flourish. The grow bed pictured here is overflowing with a variety of plants, highly aromatic basil just beginning to flower in the top left corner of the picture, red chard, white chard, silver beet, Italian parsley, long yellow capsicum and red bell capsicum plants, chives, chocolate mint, bok choi, and an ornamental fern, all growing in this rather small 1.2 metre diameter grow bed… And loving it…….!

Figure 37. Flat leaf parsley getting a little out of control.

This is a picture of the same plants as in Figure 36, a month or two later, as the weather has begun to warm up different plants have begun to take over, the flat leaf Italian parsley is starting to get a little out of control. I tried doing taste comparisons of the parsley growing in the aquaponics bed compared with the same variety growing in the ground and the aquaponic parsley won hands down, this was tested on many visitors I had, over quite a period of time and the unanimous decision was that the aquaponic grown plants were far superior in taste, with a very sweet mild flavour which was very refreshing to the palate.

It's a good idea to keep up regular plantings of seedling, and better to grow your own seedlings rather than buying them. I tend to buy maybe 50% of the seedlings I need because I'm lazy, though I always have some home grown seedling on the go.

Chapter

6

Building a System

A step by step guide on constructing a flood and drain aquaponic system incorporating four grow beds and a fish tank

Much thought goes into the design and construction of a larger aquaponic system, this chapter follows step by step through the whole process, from my initial thoughts and ideas through every step of the construction of the system. In this chapter I am specifically dealing with the system I have built in my backyard, the idea being that this can be used as a guide to build your own system, hopefully without falling into some of the pitfalls I found along the way

Initially I had to consider how I was going to house the system. The first option was a kit form green house made from a tubular steel frame with a fitted plastic cover and doors either end, a very cheap option yet certainly not the most durable or appealing. One of my major considerations was to not detract from the market value of my property and I didn't feel that a kit form greenhouse was very alluring. After a little research I settled on the idea of building a more permanent, aesthetic structure, a freestanding pergola. There are many options here depending on your circumstances. It could be as simple as taking the roof of an existing shed and re roofing with clear sheeting, or it could mean building a large more professional greenhouse, but for my purposes, a gabled roof new pergola was going to do the trick.

Building a shelter

Somehow the standard Australian steel pergola didn't seem to fit in with the idea of what I was trying to make so I followed the idea of building from wood, something easier to work with and something I was a little more familiar with. Wooden pergola kits were available from a few different suppliers at reasonable prices but I didn't feel confident enough with my construction skills to do the whole thing by myself, but at the same time I wanted to do as much as I could. After a quick scan of the local paper I found a handyman who seemed to have relevant experience. After meeting with him and explaining exactly what I was after he suggested rather than using treated pine timber perhaps I could build from recycled timbers, an option I hadn't really considered. The labour would be a little more involved as the wood is harder to work with than pine, and allowances had to be made for removing nails and painting, but then the materials would be cheaper to begin with. After a little

negotiation I explained what I had allowed as a budget since I had a price on all materials in treated pine and I figured another 50% of material costs would almost cover labour.

He agreed with the price, and plans were made to begin the construction process…

Figure 38. Site works are important, here a small shed has been removed and the washing line taken down (notice the aquaponic bed at the left).

Site preparation is another important factor as we are after a reasonably level surface for the system to sit on, in my situation I had to relocate a small garden shed and break-up and remove the concrete pad it sat on, which was no easy task in itself, the washing line and a small section of concrete path leading to it had to be removed as well. Turf had to be removed, as any organic matter left there runs the risk of subsidence in the future, and the whole area also had a slight slope to it from the rear of the block down towards the house so some initial levelling had to be completed.

Due to the slope in the area I was going to have to build up the house end about 150mm above the normal ground height, this was going to require some sort of edging and after some searching I settled on reconstituted limestone blocks 500x240x110, which were readily available from many sources and reasonably priced. The area was going to need some edging and even if I didn't need to raise the level at one end I think I would have used similar blocks for the edge as they are easy to manage and reasonably quick to install.

Within the next few days Ray arrived with his truck loaded up with assorted bits and pieces, firstly tools, then lengths of timbers of assorted sizes and shapes. Now this is where my work began in earnest, pulling nails…

After a while you begin to find a system for nail pulling which works well, pincers, hammers, crowbar and assorted blocks of wood for leverage purposes and most importantly a large tin, as it's so much easier to throw the nails into a tin as your pulling them out rather than running around afterwards trying to pick up all the fiddly little nails. In fact it can almost become a bit of an enjoyable task when you're aiming the nails at a tin which is a few metres away trying to get them in.

As the timber was recycled it was all going to need a coat of paint to have a reasonable final product and it's a damn site easier to paint timbers when they are down on the ground rather than having to paint from on top of a ladder. So while I pulled nails and painted Ray began the initial stages of construction, making 4 main roof trusses and measuring out where the posts were going to be on the building site.

Figure 39: Early stages of construction, it's hard to imagine that anything good is going to eventuate from this mess.

In this photo a couple of roof trusses can be seen after their first coat of paint. Some of the posts had a bit of a bend in them so the first thing we did was to clamp the posts all together, stacking them so that all bends would be clamped in under pressure. The posts were left like this for a week or so, and hosed down with water at least

a couple of times a day, the theory being that the combination of hot sunny days, cool nights and drawing in some water all while under tension of the clamps would straighten them out to an extent

The main posts were treated pine, treated pine was cheaper and safer from termite attack, and if these were painted as well then it will match in perfectly with the whole structure. My soil here in Perth is very sandy, and initial hole digging for the posts was becoming a problem as for every spade of sand dug from the hole, another spade full of sand was quick to fall in from the sides, and as the holes were to be 800mm deep something had to be done. This was easily remedied with water and some dishwashing liquid to help wet the sand, which has amazing water repellent properties. Although the holes were very carefully measured out we ran into some early problems half way through digging the holes, things just didn't seem to line up correctly, at least not when compared to the house. We had measured the postholes from the fence line, and although the fence seemed to be parallel with the house, it wasn't, luckily we realised this before we had gone too far because if the structure was not parallel with the house it would have been very obvious once things were finished.

Figure 40: Main structure loosely in place, it took a whole day for us to square it all up and brace it.

Once the posts were in and braced with side beams notched into the top and bolted loosely, and pre-constructed roof trusses in position, it was time to line them all up correctly before cementing into position. This is a very important phase as once things are cemented there's no going back, and it took us a whole day to line everything up perfectly before we could begin cementing the holes and bracing everything securely. String

lines are essential, we had string lines at the top of the main posts to ensure that heights were correct as well as string lines along the base of the posts, with spirit levels to check angles. Of course one very important thing to keep in mind during construction is to keep the construction area clear of obstacles to reduce the chance of accidents, the photo above shows a typical 'what not to do'. :o)

Now construction could begin in earnest, this is the more fulfilling stage, rather than the uneventful pulling nails, painting and digging holes, things begin to go up and at the end of the day it's very satisfying to be able to sit back remove the boots, open a beer, and take in the days progress, discussing what has happened and what's still to come. Often you find yourself slipping the boots back on again and getting back out there to just finish off one bit, or fix up something which doesn't seem right.

Posts are up, side beams bolted into position, roof trusses in, next in line is the roof beam down the centre, carpentry today has become a little easier than it used to be with simple brackets available for almost any type of join you can need, and these are attached with a cordless drill and screws, no need for nails or hammers any more.

String lines allow you to keep things straight and level. Here I have dug a trench to place the blocks in, a large rubber mallet was an invaluable tool for helping to get the levels right here. Place block roughly in position, then bash with big mallet until it's straight and level, easy… I didn't lay them in a bed of concrete, just sitting on the sand, however I filled in the trench on either side of the blocks with cement.

At the front end in the picture I used a fair amount of premixed concrete for added support, but at the opposite end where the blocks were buried almost to ground level I mixed dry cement and sand in the wheelbarrow and shovelled it into the trench on either side of the edging blocks. Then with a stick and a hose I poured water in while jabbing and mixing with the stick. This method worked quite well and none of the blocks have moved at all, even while using a compactor right up against the side of them.

Figure 41: Main ridge in, time to work on the edging

I now needed to build up the flooring of the structure, which I estimated was going to take about three cubic metres of road base, with temperatures between 35 and 40 degrees, I didn't really want to be shovelling wheelbarrow loads, and even in cool weather I figured three cubic metres was going to take me an awful long time to do, so I began looking into other options, that's when I discovered the 'Kanga Kid'.

Figure 42: The 'Kanga Kid' specifically designed to fit through standard domestic gates... Only just....

This little machine saved me enormous amounts of work. I had 3 cu m of road base delivered and figured that if I was hiring the machine for a day I may as well make the most of it, so I had 3 metres of mulch delivered as well. With a bucket that holds around the same volume as a large wheelbarrow, the stuff was moved in no time and the base of the area was raised to a reasonably level surface, this was all done in around 8 hours which included learning how to use the machine and dropping mulch all around the back yard.

Next phase is putting up the rest of the rafters, these can be seen in the background of the above photograph, all pre-cut to length and pre-painted, and once again no nailing involved, preformed joist hangers, framing anchors and tech screws make the job very easy, though care must be taken to ensure that rafters are mounted parallel and equally spaced between the prefabricated roof trusses. Once the rafters are up battens can be nailed on, we nailed the battens on as they were only fairly thin, and when the roofing materials go on top you don't want large heads of tech screw getting in the way, again care must be taken to try and keep the battens as square and parallel as possible.

Many different types of sheeting material for the roof are available and they come in a myriad of colours and shades and it can be a bit of a distressing subject to research, at least I found it to be as one of the only factors which I really cared about was how plants would grow under the different types of materials and colours. It seemed that the more people I asked, the more confusing it became as I had conflicting reports and of course it seemed that most salesmen were just talking up their own particular products, or more to the point, the most expensive products they had. Most roofing materials came with an extensive warranty period, however some had more fine print than others, one in particular which also happened to be one of the most expensive, required that you use their tech screws to fasten the sheets down otherwise the warranty was void, and of course although their fasteners were basically exactly the same as a standard tech screw, they were four or five fold in cost.

Eventually Ray found a local manufacturing company who produced their own corrugated sheeting made from the exact same material as the most expensive 'named' products, with the same warranty period and yet no proviso of buying any special fasteners, and the sheeting was much cheaper. The corrugated sheeting feels surprisingly like standard soft drink bottles, very soft and malleable yet surprisingly strong, this allows a little flexibility when attaching sheets as if it's a little out of square you can squeeze up one end or stretch out a sheet a bit to keep it all nice and square, something you can't really do if your using corrugated tin or fibreglass material.

Once the sheeting is in place edge flashing needs to go over the ends of the sheeting material to stop the wind getting under the edges, and ridge cap screwed down over the top ridge. Then it's pretty much all done. I did put some gutter clips down one side before putting the sheeting on, to allow for future possibilities as I may as well collect some water off the roof, even if it's only off one side of the roof.

Thought had to be given to power supplies. I was going to need some lighting and some power points, and an extension cord just wasn't going to hack it. Luckily at the time I worked for an electrical company and I'd spent a lot of time watching what went on and how things were done, but I still wanted to do it myself rather than have an electrician do it all for me, so I got stuck into it and began running wires, installing light fittings and power outlets etc. I recommend that if you don't really know what your doing then you have an electrician do it for you, it was only because I had worked in the electrical industry for the last 12 years that I felt confident enough to attempt it myself, plus I had people to check it along the way to make sure I hadn't done anything wrong. The wiring came together well and it only took a couple of days to get it all in, though without a doubt a professional would have done it in less time. However there wouldn't have been the attention to detail that I applied to it, as I didn't care about costs and time, my only considerations were quality, there was going to be no cutting corners..

For my system design I was going to need two power points for two pumps, one at either end of the pergola. Planning for the future I installed one extra power point in the middle of the pergola for using power tools etc. This ended up being a great idea and I use the extra power point often, and it wouldn't really be possible to have unplugged either of the pumps once the system was activated. I used weather-proof outlets and switches, as well as weather proof light fittings, knowing full well how water and electricity didn't go together. When I had finally finished all of the electrical installation in the pergola, it was time to get an electrician in to check what I had done, and wire up the whole thing to the meter box of the house. He ran the cable through the roof and down the inside of the wall to the meter box, taking into account the fact that I was going to have two submersed pumps and power out in an open pergola, a Residual Current Device unit was fitted to the circuit for safety.

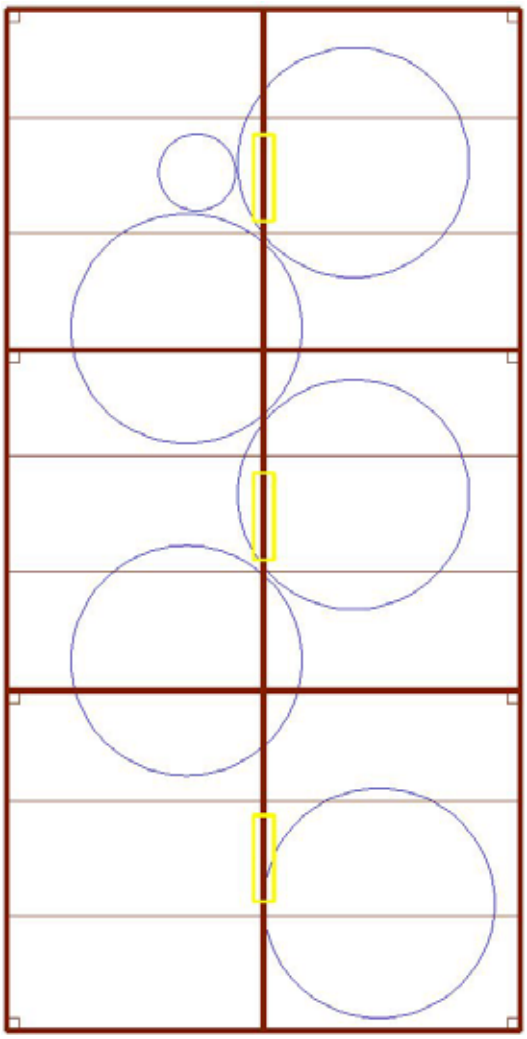
OK, power and lights were in, time to finish laying down the last edging blocks and finish the final levelling of the area. I compacted the road base, but even with a fair amount of water and compacting some areas weren't going to compact hard there were too many large rocks and not enough fine particles to bind it together. I figured that a load of fine crushed limestone would make a better surface and help bind some of the courser road base into a better base to work on. The limestone was very cheap and improved the binding properties and aesthetics of the area no end, but most importantly I could now walk on the surface with bare feet without suffering from the sharp rocks.

Compacting of the area is important if the ground is freshly disturbed, as once the beds are in position filled with gravel and water they will weigh close to a ton and a half, and if one of the supports is sitting over an area which might subside it could lead to messy problems. After compacting the road base very well, I spread the limestone on top and compacted again only to have an area the size of a small Frisbee suddenly subside and drop down around 15cm. This subsidence happened in the area where a shed used to be, the shed sat on a concrete slab which had cracked in a few places over the years and after breaking up and removing the concrete I noticed that there was a fairly large amount of buried rotting timber under the old shed slab. I could only conclude that at some stage there had been a large tree where the shed stood and these were the remaining roots and bits of stump that had been slowly rotting over time.

Now it was time to start finalising my design plans, I had the structure for housing the system pretty much finished off so now I had to make the decisions on final tank sizes so that I could order them to be custom made. During years of experimenting with different sizes and ratios of fish tank volumes versus grow bed volumes, it's been found that one of the best ratios is 1:2 fish tank volume to grow bed volume, this allows maximum stocking densities in the fish tank while allowing enough grow bed volume to filter the water. One of my more limiting factors was going to be space. I was going to be working with round grow beds and a round fish tank while trying to place them all into a square or rectangular area. Easy you might think, but there are a few factors which need to be kept in mind while at this design stage.

As this is a flood and drain system, the beds will be flooded with fish water, then allowed to slowly drain into a sump or drain tank which will then periodically pump back into the fish tank, I'll cover the whole operation in further detail later, but the important factors are piping and the drain tank. The piping from the fish tank to the grow beds isn't so important as it can be up in the air out of the way, but the drains from the bottom of each grow bed, into the drain tank have to be low as it's gravity doing all of the work. All of the grow beds have to be draining into the one drain tank which means the positioning of the beds has to allow them all to drain into the drain tank without pipe work getting into the way of your accessing the grow beds for planting and harvesting. If you were to be stepping over pipes in your day to day visiting of your aquaponic system it would soon become a chore, and what's more, hazardous. There nothing kids like more than climbing on things and PVC pipes aren't known for their strength.

Luckily due to my profession I have to use CAD (computer aided design) on a regular basis, this made things very easy to try many, many different designs without having to physically move anything. Drawing up the different designs to scale allowed me to get a pretty good idea as to what will work and what won't before I had to actually buy anything.



Once I had the pergola built I could draw it to scale in CAD and then start playing with different sized tanks and different arrangements of the tanks. There are many cad programs available which can be downloaded from the internet for free and installed on your computer. They are an invaluable tool for designing, the most noticeable advantage being that everything can be drawn to 1:1 scale, so there is never any doubting whether something will fit or not. The other advantage is for material takeoffs, once I had drawn my design I was able to measure all the lengths of different sized pipes easily.

As I designed the layout of my system I was taking into account such factors as allowing plenty of access around all areas so that while it was raining in winter you wouldn't get wet while planting or harvesting, trying to keep the area reasonably uncluttered in general, allowing more area around the fish tank, and as I mentioned before, allowing all the grow beds to be piped into the drain tank without the pipe work getting in the way of accessing the grow beds.

After maybe fifty or more variations on tank sizes, grow bed sizes, and general layouts, one of my original layouts just seemed like it had to be the right one. All other designs seemed to have at least one flaw in them, where as the only problem with my original design is that it's not the most economical use of space. This didn't concern me too much however as it was purely a prototype to prove that the system was going to work, now that it's proven, the layout of the components and their sizes can be juggled to fit into whatever space is available in future designs.

Figure 43: The layout which finally made it over all other designs.

To make things a little easier I have the main fish tank and grow beds all the same diameter, 1.8 metres. The main fish tank is about 900mm high, giving me a volume of around 2.1 cubic metres when almost full, while the grow beds are just under 300mm high, giving a total volume of almost 3 cubic metres for the four beds. It didn't quite work out at the magical ratio of 1:2, but 1:1.5 will allow me to have some pretty reasonable stocking densities of fish.

Building Grow Bed Supports

Now I had all of my tank sizes sorted out I had to figure out how to support them. Many, many hours were spent pondering this problem, speaking with different people about possibilities and researching all possibilities. One avenue I really liked was to use a round concrete soak well of about 1.2 metres in diameter as the main base, with a soak well lid with a diameter of 1.8m, so that it over hangs the smaller soak well underneath. Most lids can be provided with inspection ports or holes though the lid at one edge, which would allow the drain from the bottom of the tank to be fitted. The price was the main drawback, as well as the fact that each lid was going to weigh almost a ton and a half, that was going to be a little too much work to try and organise and manoeuvre, however I feel once bought and erected the aesthetics practicality and simplicity of this support method would be exceptional.

The main factors which must be kept in mind when deciding on support structures for the grow beds are that they must be able to support large weights. Beds the size of mine filled with gravel and water, weigh at least one and a half tons each. Also you have to be able to get the drain pipes to the drain tank with as little hindrance as possible, taking into account that the drain pipes will spend much of their time filled with water they need to be supported, and if you ever need to remove the drains for cleaning or repairing you'll be thankful that you took this into account early in the design process. Steel grow bed supports may be your best option if you know how to work with steel, or know someone who does, but personally I have no metalworking skills whatsoever, and no metal working tools either so I went for the most cost effective option considering the skills and tools I had on hand.

When I built my original smaller system I built the bed support from treated pine timber 100mm x 50mm, however this grow bed was only 1.2 metres in diameter and nowhere near the weight of the new system, so not such a viable option in this case. Concrete brocks and limestone blocks come in many shapes and sizes, and prices as well, and it didn't take too long before I realised that the solution for my needs was going to be along the lines of 'block' pylons or legs supporting a wooden frame directly underneath the grow bed tank. In an early design plan I had incorporated six legs made from blocks of a similar size to the ones I had used for the edging around the pergola, they would need to be stacked three tall, making eighteen blocks per bed.

Figure 44: Tanks have arrived and I'm still not sure which supports to use.

A decision had to be made as the tanks had arrived. After discussions with friends I settled on the idea of large reconstituted limestone blocks. The blocks were 500 x 240 x 350, pretty decent size, very cheap, and standing them on end means I had all the height I needed using only four blocks per bed with large beam supports across them. I was a little concerned about the stability of the whole structure. I could see the potential for a possible accident if something heavy fell against the bed, with a ton and a half balanced on top of four blocks I had to be reasonably certain of the stability. This was the point when a friend of mine, Chris suggested dyna-bolting the timber beams onto the blocks, then nothing could topple it.

Figure 45: Dynabolts bolting the beams to the block supports was going to be the answer for stability.

Once the tanks had arrived it didn't take long to shuffle them around and get them into position. When I was happy that they were lined up in their final positions I used a bottle of string line chalk to mark around the edges of the tank, to guide positioning the blocks, before removing the tanks. With blocks this size it's a damn good idea to get them as close to their final position as possible the first time around, as they weigh 83 kg each. They weren't too difficult to manoeuvre into position once you had a system worked out. Push them straight off the back of the ute onto the lawn, then use a furniture trolley to pick them up and move them. If you tip them onto the trolley in their vertical

position then it's a simple matter to wheel them onto the site where they are required lean them off the trolley and whip the trolley out, simple.

To judge the positions of the blocks I used the CAD design software on the computer, I had it all drawn up to scale and I played with it in the evenings until I got the layout of the stands looking just right. It does require a little thought when your trying to design a stand which is as small as possible to allow unencumbered access for myself and pipe work, and it's combining square blocks, straight timbers and round tanks. When I had everything looking about right on CAD I could measure the distances between the 'virtual' blocks, then all I needed to do was zoom in on the particular area I needed and print it out on paper, then I could bring it out the back and follow the designs as I went.

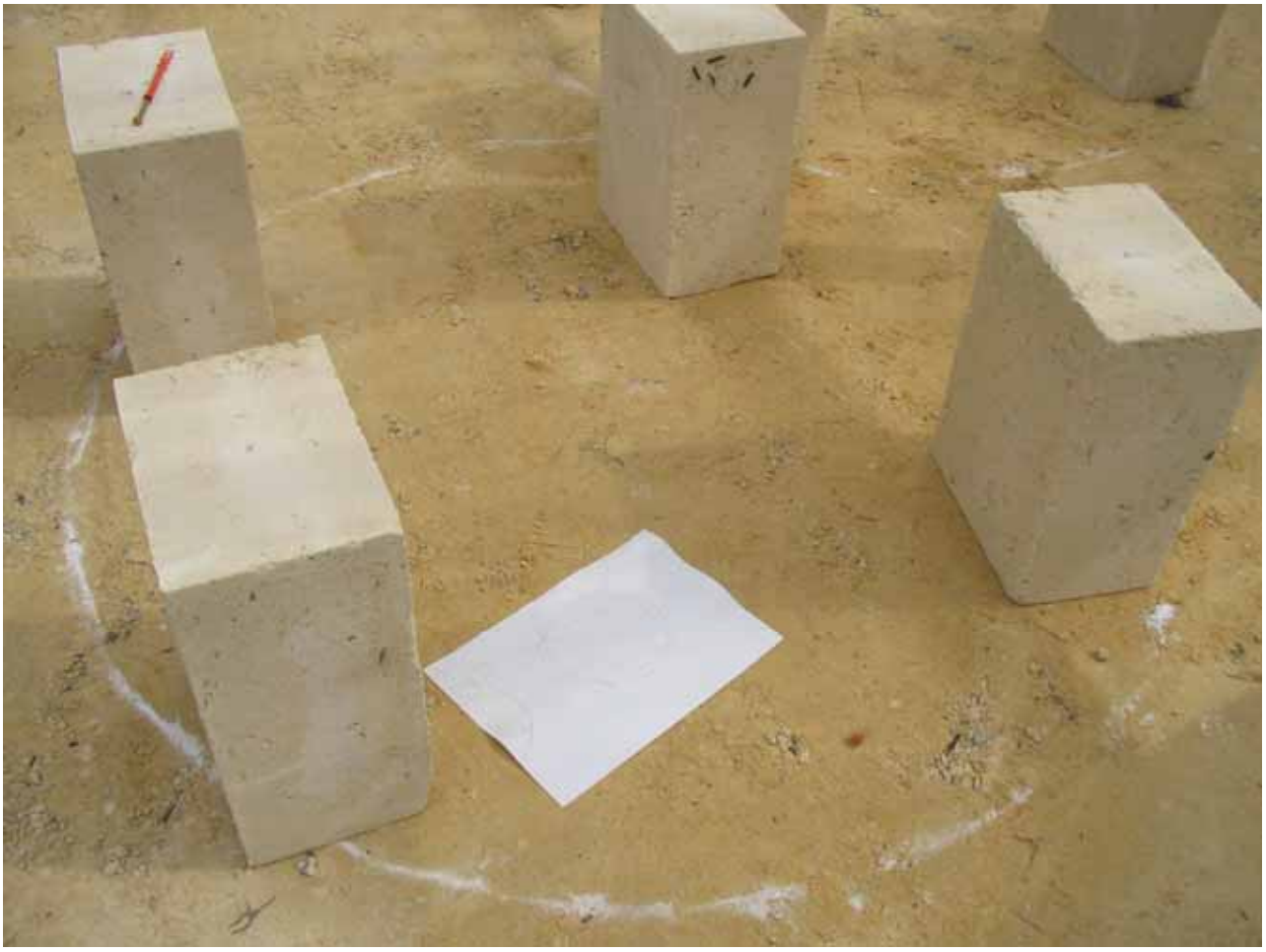


Figure 46: Layout plans printed during construction was a very handy tool.

Two beams were to then be placed across between the limestone blocks. The timber I chose for this was 100mm x 75mm karri beams, karri is a local tree to Western Australia and I felt a little uneasy about using the karri when I see how quickly our forests are disappearing in the south west, but I was left with only a few choices as I didn't feel pine would be strong enough, so it was going to have to be a hard wood and in deciding which hardwood to use it's almost a case of deciding which country or state is going to have to cop the loss of their native hardwood forest for the benefit of your project. Still it's only a couple of lengths I'm going to need and hopefully the benefits which will eventually flow from the system I am setting up will far outweigh any

negative environmental costs involved. The beds were also going to require a fall down to the drain end of the tanks to allow the water to drain well and completely to give this extra height to one end I used short pieces of the timber used for battens when we made the pergola 30mm x 65mm with a 20mm whole augured through the centre to allow the dyna-bolt to pass through into the limestone block. Using the hand auger with a sharp spade bit was very quick for drilling through the wood that was then cut into the short sections to fit under the beams. Holes in the beams were countersunk with the same auger so that when it came time to position the battens on top there were no dyna-bolt heads to interfere with positioning.

Figure 47: beams being bolted into place with spacers under one end to allow for a drain fall.

OK, the centres of the blocks were determined by drawing diagonals from the corners of the blocks, then holes were drilled with a masonry bit. Before putting in the dyna-bolts we dipped them into a little dishwashing liquid to allow for easy insertion. Care must be taken when tightening the bolts not to tighten them too far. Of the 16 bolts that went into this system we broke around a quarter of them, some broke during tightening and others broke shortly after while trying to realign things after they were all bolted together.

Figure 48: Checking levels and squares.

Notice that all the beds are sloping into the centre as all drains are going to be roughly down the centre line of the pergola. The levels were checked but unfortunately it's very difficult to adjust things once you're at this stage, aside from wiggling the blocks a little to try and bed them down better, or lifting the end of the timber, thus lifting the block while someone else quickly tries to get a little sand under the block, there's not a great deal you can do. Lifting the blocks at this stage you have to be careful, this is how we broke a couple of bolts, it's far better to take a little more time before hand to ensure that your whole area is level. Luckily it isn't too much of a problem if things aren't perfectly flat anyway.

It was at this stage I realised another advantage of only having 4 supports for each tank, if I was to have had a third pillar or block under each supporting beam it would add a whole new set of problems, it's far easier to balance a beam across two support, once a third is added to the middle then shims would need to be inserted under the beam to spread the support onto all pillars, using only two allows for a little extra fudge factor.

For the tank supports I've used 90mm x 35mm treated pine slats nailed across the main beams. It was a bit of guess as to whether these were going to be suitable supports for the weight of the tanks. I used a highly technical method for my assumption that this sized timber was going to be suitable. Cut a 1.8 metre length and place it across the beams, then I stood on it in the centre and jumped up and down a little and it didn't break…

My reckoning worked by using a very technical formula I devised for calculating the load bearing, the 'fat bastard' theory. This theory can be adapted to all decisions when trying to estimate sizings for the support structure. I found it quite difficult to try and quantify things like 'a ton and a half', it sounds like a lot , but just how much is it, and what is required to support such a weight? I couldn't think of anything which weighed a ton and a half to try and get perspective as to whether the different facets of the support structure was going to be sufficient, this is where the 'fat bastard' theory comes into it's own, bringing things down to an easily identifiable level.

Ok, fifteen hundred kilograms (1 ½ ton) could also be represented as fifteen fat bastards who each weigh one hundred kilograms, now if there are the four supporting limestone block distributing the weight that means there would be less than four fat bastards standing on each block, well they can easily support that, they are very substantial blocks. Now how about the beams, there are the two beams so they will be carrying half the total weight each, that's less than eight fat bastards each standing along the beam, these 100mm x 75mm beams could easily carry at least twelve fat bastards each surely.

I'm using 9 battens across the beams to support the tanks, this weight would be evenly spread allowing for a little over one and a half fat bastards per batten, spread over the whole length of the batten. Therefore for one fat bastard to stand right in the middle of the batten and jump up and down without causing any problem, the battens were going to be sufficient for the purpose, if not overkill.

To design the layout of the battens I used the CAD again before even cutting one piece of wood. I began by placing the central batten down at 1.8 metres long, then I spaced the next couple of battens out from this one on either side at 100mm spacings. The end battens were then placed into position at the end of the beams, with the last few battens evenly spaced in the gaps that were left, this gave them a spacing of around 130mm.

Without having the aid of CAD it would have been difficult to figure out the spacings and lengths of the battens but drawing it all up before hand to scale allowed me to determine all the timber lengths, so there was no messing around laying pieces of wood on top of one of the tanks trying to measure manually how long individual pieces needed to be. Once I had it all designed I just printed out the lengths and gap dimensions and off I went to cut the predetermined lengths, yeah I thought I was just too smart. Unfortunately I quickly discovered that the tanks were actually 1.85 metres diameter at their base, that'll teach me, I guess that would actually give them an average diameter of about 1.8 when you take into account the ripples of the corrugations.

This threw the calculations out a little bit but it wasn't a major catastrophe, I guess one of the worst aspects was that I had designed and cut the main support beams to 1.8m, I guess that was going to mean about an inch overhang on either end. I made allowances for this by overhanging the end battens a little over the end of the beams.

Figure 49: Battens going into place pre-measured and cut, though a little trimming once in place is required for some.

Something I hadn't taken into account was the intersections between the different grow beds. Of course because of the design and trying to maximise space, the beds were really crammed in together and the battens were pretty much butted up together from one bed to the next in some places. This wasn't too difficult to deal with though, once I had the first one built and was beginning the second, I placed the grow bed tank on the first stand and wherever there were potential clashes of battens I marked the outline of the tank on those battens. This then allowed me to cut any extra off the battens, and with a little juggling and fiddling in this way, things were beginning to come together.

Once the battens are all in position it's time to think about drain fittings. There were different sized drain fittings that the tank manufacturer offered to insert into the tank but the standard tank fittings are rather large. That is, when the fitting is attached to the bottom of the bed, the inside thread of the fitting was going to stand proud of the bottom of the grow bed by at least 15mm, I wanted the beds to be able to drain as freely as possible so had to find an option with a lower profile.

Local hardware or plumbing stores sell many assorted shapes, sizes and designs of shower and laundry drain fittings, I found that a 50mm shower drain was going to be the ideal answer for the system. Once all the grow

beds were in place and I was happy with their positioning I carefully marked where the batten supports under the grow bed were positioned so that I could be sure to drill the drain hole in the correct place.

The Drain System

Figure 50: Drain hole placement and sealing is a vital aspect.

The hole needs to be drilled slowly through the steel as it will heat up very quickly. Stop frequently to allow for cooling. When the hole is drilled clean out all the metal shavings from the bed, trying to keep dangerous metal shavings out of the system and pumps.

When installing the drain fitting I used a large amount of silicon sealer, and I mean excessive. I don't want to find out a month or two down the track that it has sprung a leak and I'm going to have to start shovelling gravel again. I also used large amounts of silicon on every single surface, under the washer, around the metal, under side of tank, on the threaded retaining nut underneath. Then tighten it all up and smooth out the globs of silicon squeezed out with a very wet finger, this will allow the water to flow into the drain as freely as possible.

Once all of the drains are in, its time to put in the growing medium. First the drains must be kept clear of gravel to allow for clearing blockages and monitoring water flow. The ideal item for this task is some large diameter pipe, I used 150mm pipe as it was readily available.

The pipe needs to be cut into lengths about equal to the depth of your grow bed it and sit directly over the top of the drain hole, allowing access. In the bottom end of the pipe I cut slots into the pipe a little to allow water in the very bottom to drain through, then I filled the pipe with 6mm holes, as can be seen here in Figure 51.

Holes need to be concentrated towards the base of the pipe as these holes will drain more effectively. Also when sawing the lengths of pipe off to the correct depth to sit in the grow bed, you have to be careful to make a square cut. A wonky cut will not sit flat on the base of the grow bed, and if you ever move it or twist it will allow the gravel rocks to get under the edge. Care has to be taken once it's in place and the gravel is in the bed, not to lift the pipe at all as once the gravel gets lodged under the end of the pipe it's very difficult to get the gravel out from under it and push it back down again.

Figure 51: In bed drain pipe, showing holes for drainage of water

You must keep the pipe on the base of the bed as you don't want gravel getting into your drain pipes and drain tank.

The Growing Medium

Work begins in earnest now, one of the more difficult stages of the construction is filling the beds with gravel, not that it's, but each bed will hold a little over a ton of gravel, so there's over 4 tons of gravel all up, or should I say a little over 40 fat bastards, that's a lot to shovel when you think of it that way.

It could be an idea to bang in a few nails around the edge to hold the tank in position while your filling it, especially if you are using some type of ramp, or your lifting the wheelbarrow up and tipping the gravel in, these methods are prone to moving the bed during the filling process.

In my first system I used cracked gravel but I found this very difficult on the hands when planting and digging into the gravel, so this time I decided to use a straight pea gravel. Here in Western Australia that means a dusty red bauxite gravel, it's the sort of material which never seems to stop producing red dust which the outback here is quite famous for. I only hoped that it wouldn't keep producing dust while in my grow beds. There's also quite a percentage of stone chips even in the pre-washed gravel, as much as possible of the stone chips and dust needs to be washed out before you fill the beds with it. The chips and dust when mixed with water tend to become a sludge which will adversely effect the water flow in your grow bed over time. But how the hell do you clean gravel? A good method would be to use a screen of some sort and water. You can use an angled screen leading into your wheelbarrow. You drop gravel onto the screen as water squirts over it, with the gravel rolling down the screen and into the wheelbarrow, while the chips and dust washed off through the screen beside the barrow.

Figure 52: Shovelling the gravel was one of the more physical aspects of building the system.

I began without a screen. I reversed my poor suffering, sagging landcruiser up onto the lawn with the gravel load on the back, and then I used the hose to squirt down the gravel washing the chips and dust down through itself. After a bit of washing with the hose, I filled the barrow while carefully watching what was being shovelled to see that I wasn't picking up chips. As the load got a little lower the concentration of rubbish became greater. This is where a nail rake comes in handy, raking up the gravel into piles while washing it with the hose. And of course it needs to be shovelled off at the other end as well, unless you have an offsider to help out, a second person was invaluable during this gravel process with only average sized barrow loads two people could grab an end each, lift it up and tip it into the bed, there's half the shovelling taken care of. Even better if you can rope some kids into helping, what kids wouldn't want to be on the back of the ute with a hose and a rake playing around, especially when there's promises of play station when it's all finished. Of course you have to carefully place your 150mm in bed drain pipe full of holes into position early in the piece. Just place it centrally around your drain hole, holding in position with one hand as you pull the gravel around it to keep it in position, once the gravel is in place it won't move unless you pull it up of course which would be a minor catastrophe. As you begin to fill each bed it is advisable to check and be sure that the bed is still in the exact position you want it, as after you begin filling there's no moving it.

Figure 53: The irrigation grid and other pipe work starting to take shape.

The Irrigation Piping

Once the beds are filled with gravel you can begin making your irrigation grids, these are very simple to make as it's a straight forward grid pattern beginning in the centre of the bed with a cross joining piece, radiating out from the centre at around 30cm spacings, I kept all of the pieces of pipe the same size, so basically there are only 4 different lengths of pipe in the whole irrigation grid. Irrigation grids should not be glued together, it's enough just to push the fittings hard together. This will be sufficient as there is little pressure on the fittings so far from the pump and close to the outlet holes. The reason for keeping the fittings on the bed unglued was brought home to me recently when I had problems with my original aquaponic system becoming clogged, I had made the mistake of planting mint in the grow bed, and then I had made the even worse mistake of leaving it for many months, letting it take over the grow bed. I'd glued together all of the fitting on this system, but had used a couple of removable couplings so that I could remove the whole grid from the bed and when I took the grid off I was shocked to find the mint had grown into the grid irrigation pipes, through the irrigation holes drilled into the bottom side of the pipes. I tried for some time to get the mint runners out of the irrigation pipes using bits of wire and a hose but to no avail, and as the fittings were all glued together I had to cut the end caps off the grid. The irrigation pipe was clogged with mint stems, the whole length of the pipe was filled with the mint.

Figure 54: Mint plant clogging the irrigation pipes of the aquaponic system.

I learnt my lesson here and there's two things I won't be doing again in a hurry, I won't be gluing any pipes which come in contact with the bed, and I certainly won't be planting mint again in any grow beds, mint is best left for growing in a pot a long way away from any other ground.

There are a number of other options which could be experimented with for irrigating the beds. The method I used is expensive as the pipe fittings were not as cheap as I expected them to be, and I plan on experimenting with a different method in my next system. For these round beds I probably should have tried black Philmac fittings, Philmac fittings are much cheaper and there's more variety in fittings also, one particular fitting I almost used was a '*' type fitting. One central fitting in the middle of the bed which accepts a vertical input line from above, and then radiates six equally spaced irrigation lines outwards toward the edge of the bed, just like * (an asterisk) when looking from above.

Philmac pipe and other fittings are cheaper than the PVC fittings I used, so if cost is a deciding factor when designing your system this would be a viable option that should be investigated. Though I did have concerns about using this option because the pipes and fittings are black and as such will heat very quickly in the sun, especially in summer and scalding hot water pumped straight out onto the roots of plants is not good, even if the water wasn't sitting in the pipes between pump cycles, the pipes will still heat up to a very high temperature and the initial flush of water could damage plant roots. Of course the problem isn't as great when the grow bed is full of plants, as the plants tend to shade the irrigation grids sitting on top of the gravel This could be dealt with though by painting the pipes a lighter colour.

However, that's all in the future, and maybe a different book, for now I had the rest of the pipe work to install and more gravel to shovel. After filling the first two beds with gravel I made sure there was enough irrigation pipe work installed so that I could use the pump to help clean and flush the gravel. Although the gravel has already had a wash before loading into the beds, there's still a lot of cleaning and flushing required and this can readily be achieved by setting up temporary drains out from the bottom of the beds, off to the side of the pergola and using a combination of the hose and the irrigation system to flush the red dust and stone chips out of the beds and off to the side of the pergola.

I was concerned here at the amount of water required to flush the beds out, as it takes a while for the water to begin to flow cleanly. When cleaning the gravel like this it's a good idea to use a combination of methods to be sure you flush as much rubbish out as possible. Use the garden hose to slowly cover the whole surface area, don't fan the water flow, just let it flow straight out and only move it very slowly around the bed, allow an area to have a really good soak with the hose in the one spot and watch the red dust flow out. You have to think along the lines of erosion, your trying to erode all the muck out from in between the gravel and out of the tank, so you need concentrated flows of water rather than a light sprinkling of water over the whole bed.

Figure 55: The first two beds filled and being cleaned.

Having hosed the beds well, get the piping to a stage where you can put water in the fish tank with and flood the beds with the irrigation system. The drain fitting installed in the tank came with plugs supplied, so I plugged the drains, turned on the pump and let the beds fill with water. This helps to dislodge more particles and aided greatly in the general cleaning of the bed.

I flooded each bed at least three or four times and had the hose running on each bed for probably a total of at least an hour, to me this seemed like a huge amount of water to be wasting, but then in reality it's not being wasted because the system is going to save water in the long run and it wouldn't be long before it had made up for and exceeded any initial water indulgences. Many people wouldn't think twice about leaving sprinklers on for hours at a time. I guess ultimately it would be best if you are constructing your system in the middle of summer and you could take a little more care in reticulating your waste wash water around the garden to better effect rather than pouring it in one spot.

All the irrigation pipe work is kept up in the rafters out of the way. At this stage you can walk on the grow beds to get up there, though it's a good idea to glue as many fitting as possible on the ground before putting the pipe work up, as when your gluing the pipes up above the beds excess glue often dribbles down onto the gravel. I used cable ties to temporarily support the pipes wrapping the cable ties around the roofing timbers, then around the pipes to hold them in place, the cable ties worked well for this purpose although ultimately I plan on replacing them with saddle clips to attach the pipes firmly to the timbers.

Above the pump in the fish tank I installed a non-return valve, this is important for the pump, it keeps the water in the pipe above the pump meaning that the pump always starts primed and with a head, your pumps will last longer if it's done this way. About 600mm above the non-return valve I installed a removable coupling to allow for easy removal of the pump for maintenance and in case of pump failure. The main irrigation line leading out from the fish tank was piped up into the roof and down the length of the pergola with 40mm PVC pipe to allow for maximum water flow. Separate leaders which came off this main pipe, led to the individual grow beds in 25mm pipe, with each bed having a ball valve high in the air directly above the bed (see figure 55). All pipe fittings up to this ball valve were glued for strength, then all fittings below the valve down onto the bed were just pushed together. The ball valves were mounted high in the air so they were out of the way from prying hands as once the setting for flow to each bed has been adjusted you don't want anyone to play with it. Even a small adjustment on one valve can make large differences in the whole system. Ultimately I would recommend gate valves rather than the ball valves I used. Gate valves are highly adjustable as it takes a number of rotations of the handle to work the valve from fully open to fully closed, where as the ball valves I used required only a ninety degree rotation to adjust the valve from fully open to fully closed. When trying to adjust the flow to individual beds it was very difficult to set the ball valves I used, and it took days of fiddling and even then I still haven't got it perfect.

The drain return piping is in 25mm pipe, with a non-return valve directly above the pump, and then maybe 600mm above that a removable coupling. One concern I had about the system was that I wanted to be able to pump water out of the whole system if need be. After much consideration I decided the best place for an outlet would be in the return line, so just above the removable coupling I installed a T-piece and plug. If for any reason I want to pump out of the system rather than back to the fish tank I can remove the plug and attach a hose, then push a cap onto the return outlet above the fish tank, forcing the water to be pumped out to the garden through the hose rather than into the fish. I could see great promise for this idea if I wanted to clean a bed filled with algae and other gunk, switch the system off, clean the bed, attach the hose to return line above the drain pump, then flush the bed at will, safe in the knowledge that it isn't going to end up back into the fish, but rather in the garden where it will benefit the plants. This is in keeping with the whole basis of aquaponics, making positive use of waste, turning negatives into positives.

The pipe from the sump tank to the fish tank follows along in the roof with the irrigation piping, returning to the main fish tank. Here the water is returned to the tank, oxygenating the water at the same time. I was a little concerned about the noise, my fish tank was only about six or seven metres from my next door neighbours bedroom window, this probably wasn't too much of an issue at the moment during the initialisation of the system as it's winter time and generally all windows are closed. This system was going to be going twenty four hours a day every day, and it's not going to be very pleasant to be woken at three in the morning when the return pump kicks in and water starts splashing back into the fish tank. This is where a friend Chris came up with a winner of an idea, while fiddling with bits of pipe and water, as you do when your building an aquaponic system, he came up with an idea which suppresses a large percentage of the noise yet still seems to provide very good aeration. I haven't been able to check exactly how it affects the dissolved oxygen levels in the water, but I plan on having a supplemental bubbler for the fish tank anyway so it's not a major concern.

While fiddling around, we discovered that if you slipped a piece of 40mm pipe over the 25mm return pipe and submerged the end into the water, it greatly reduced the sound emitted, yet at the same time seemed to inject the bubbles deeper down into the water, almost to the bottom of the tank. The 25mm pipe was cut off around 300mm from the highest water level and as the water is pumped in it draws air down from the top of the 40mm pipe, down between the two pipes and it's injected deep into the water.

Of course it had to be self adjusting to the height of the water as this was going to be constantly varying through different stages of the cycle, The one constant we could keep was the distance that the 40mm pipe went into the water, around 200-300mm seemed like an optimum level from trials, so I got a float for a crab pot from the local tackle store and used the hole saw to drill a hole through it big enough for the pipe. To hold the float in place I used a couple of galvanised nails, wedged between the pipe and the

Figure 56: The noise suppressor, even engineers come up with good ideas sometimes... :o)

float, this worked well holding the float about 200mm from the base of the pipe, hence the base of the pipe is around about 200mm below the water level, and stays at that depth no matter what the water level in the tank is.

As the final two beds were filled with gravel and their final in-place flushing and washing began, I installed the first two beds drain piping in place so they would drain into the drain-return tank. This was when I learnt an interesting lesson, there is a difference in irrigation pipes and pipe fittings, and drainpipes and pipe fittings and they are not meant to be joined to each other. I had bought fittings for 40mm drain work and I had bought normal irrigation pipes and fittings, but these do not join into drainpipe fittings. All drain fittings and pipe are grey in colour, and they have imprinted on them 'DWV' drain, waste and vent. I tried in vain to find adaptors to join the two types together, before resorting to buying all new fittings and pipe of DWV type for my drain systems.

The drain pipes are going to be heavy when full of water so care has to be taken to support the pipes sufficiently as there will be too much weight to be supported on the fittings along, this can easily be done with electrical cable ties. Using the cable ties requires a bit of grovelling around on your back under the grow beds but it's advisable to spend the time carefully tying up the drain pipes at least every metre or so, to the wooden frame work of the bed supports. I left one short drain unsupported, and it popped off the bottom of the shower drain fitting because of the weight of the water in the pipe, causing a major flood.

Originally I planned on gluing the drain fittings in place using pvc pipe glue, just as all the other irrigation fittings had been glued, but after some contemplation I decided to use silicon sealer on all drain fittings. I wanted the drains to have a little bit of flexibility and PVC glue has no flex where as silicon has a fair amount of give.

Figure 57: The drain tank with all drain pipes capped and running.

Once the final two beds had been flushed sufficiently and the water flowing through was clean I finished of the drainpipe work so that all beds now drained into the sump tank. I found my sump tank was a little too high to get the pipe work to sit on or above the rim so I had to dig the tank into the ground about 100mm, this allowed all of my drain pipes to have a fall sufficient to drain well into the tank. Realistically very little fall is needed on the drains as the pressure of the water in the is enough to force the flow into the drain tank.

Flood and drain Process

To slow the whole cycling process of flooding the beds and draining, end caps with a few 6mm holes drilled through them are used on the end of the drainpipes. This causes the beds to fill quickly, and then drain slowly. Then bit by bit as the sump tank fills the return pump is switched on to pump the water back into the fish tank. After experimenting I found that for each time the fish pump turned on to fill the grow beds, the drain return pump switches off and on about 10 ten times as it pumps the water back into the fish tank bit by bit.

Before construction I was confused about the concept. I couldn't quite comprehend how it was going to work but the whole system fell into place with a little fiddling.

Firstly I had to set the main pump in the fish tank so that it was going to pump enough water to fill the grow beds and then switch off automatically, then remain off until the water had all been pumped back into the fish tank before switching back on. This is done using the automatic cut off float switch attached to the pump. By attaching the float switch's tether at the right height with the right length of tether out to the float, the pump will switch on when it reaches full, then off when it has pumped down to the level required to fill the grow beds. This took some initial adjustment.

My pumps didn't have enough length in the tether cable on the float switch to allow me to sit the pump on the bottom of the tank and have the float switch operate correctly. So I had to start experimenting. I made some enquiries and discovered that the cable that tethered the float could be cut, and an extra piece of electrical cable could be added in and sealed onto the original cable to create extra length on the tether and the whole length would be waterproof. I had one metre of cable inserted so that I'd have more than enough for what I needed, then began the process of testing it to see that it could be mounted at the right height in the tank, and have enough movement to allow the float to switch the pump on and off as I needed. When joining the bits of cable together a heat-shrink sleave is slipped over the join and the two pieces of cable, this sleave is then heated and forms a waterproof seal but unfortunately where the heat-shrink sleave is heated and moulds onto the join and cable, it becomes quite stiff. Because the cable had lost it's flexibility right at the point where I wanted to have it pivot it was of no use to me.

Figure 58: pump set to the right height with the right tether length.

Luckily I had a spare pump just in case so instead of trying to raise the float switch up to the surface of the water, I moved the whole pump. My pump sits on three bricks, and it didn't take long to figure out the correct height with a little fiddling, lifting the pump up and down in the water while playing with the float tether. During the process of washing the gravel I had quickly discovered that it took about one 'rung' of water from the fish tank to fill one grow bed, so four grow beds would require the float to switch on and off, with a vertical travel of four rungs in the tank.

Notice the tether tied on with stainless steel hose clamps and a cable tie. After an initial rough setting to get it to the correct height it didn't take long to get it exactly right. One small adjustment with the hose clamp to lower the float as it wasn't turning the pump on.

Then pull the tether out a little longer from where it's attached with the cable tie, as the pump wasn't quite pumping enough to fill four grow beds. With those two minor adjustments it was set and I haven't changed it since as it cycles beautifully. The sump tank pump didn't need to be touched in any way, I just dropped it into the sump tank with the float attached as it was supplied from the manufacturer and it switches off when the water level is down to 60mm, then switching back on when the water level reaches around 340mm.

I ran into a few problems trying to get the water levels into the individual beds at the right rate, the plan being that the water should fill up to just under the surface of the gravel. If water is on the surface of the gravel the sun will cause algae to grow in the bed and restrict the water flow. If the water level is to low in the grow bed the plants won't be able to get the water they require. The problem I had was really with the valves I installed above each bed, they didn't have enough adjustment in to set the flow rate accurately. I spent days adjusting the different valves, each time I closed a valve just a little bit, it would cause more water to be delivered to the other beds, then when I opened one just a fraction the bed would flood and the remaining beds would remain too dry. A little lateral thinking was required, I didn't want to change all of the valves, I was after a cheaper answer, and this is it.

Figure 59: Standpipes are a more viable option for controlling the water height and drain flow.

A standpipe, these are commonly used in many varied applications to control water levels. My drain control of the beds was by using a standpipe on the drain outlets in the beds.

I began experimenting with many different ways of trying to get different sized pipes seated into the shower fitting in the base of the grow bed, but nothing was going to work so I gave up for a while until a friend discovered that the standard 50mm rubber sink plugs which came with my shower drain fittings fitted perfectly onto the end of 40mm pipe.

Four pieces of pipe were cut to a length so that they sit at around the top of the gravel or just below it. Two 6mm holes are drilled just above the plug, once the plug has been firmly fitted onto the end of the pipe, and the very centre of the plug was carefully cut out with a sharp knife.

The notches in the top end of the standpipe are best left until you see how your fill levels are in each individual bed. If a bed is filling too much cut a V in the top, if it still fills too much, cut a little more out of the V making it deeper and wider. If any bed is receiving too much water, the water flows over the top of the pipe and straight through the drain into the sump tank. The normal drain water flow is restricted to only the two 6mm holes. This works well for these sized beds, and is far better than using a cap with holes on the end of the drainpipes.

Figure 60: The standpipe worked well for controlling both water levels and flows.

When using the standpipe it means that there is less water pressure in the drainpipes. I was having a fair amount of trouble trying to plug all of the leaks in the drainpipes and fittings with silicon in the original set up. Because the capped pipes had a great deal of water pressure behind them this caused the water to shoot out of the holes in the end cap at a great speed which cause a fair amount of splash as well as noise. I had to cover the drain tank with pieces of timber off cuts left over from construction, this helped keep the noise down a little but it was still disturbingly loud at early hours of the morning, which was unfair on the neighbours.

Once I began using the standpipes instead of the end caps on the drainpipes the water only trickled out into the drain tank making very little noise, with the pieces of wood over the top of the tank as well there was hardly any sound.

Initialising The System

Initialising the system to get it all going was fairly simple. I added around 500ml of SEASOL seaweed extract to the fish tank, and left the system cycling for a couple of days. I then pumped the water out of the system and filled the system with fresh water leaving this to cycle for a couple more days, during this period I used some bacteria from the grow beds of an existing aquaponic system to inoculate the grow beds of the new system.

Figure 61: system at first initialising with seeds and seedling just planted.

The idea of inoculating the beds is to aid the growth of bacteria in the gravel. The beneficial bacteria will eventually grow in the gravel beds without being added manually, as the bacteria are all around us in nature and given the right situation, will propagate. Addition of bacteria directly from an established system into the gravel gives the bacterial population a head start in becoming established in the fairly sterile gravel bed. This was also my idea behind flushing the system with nutrient rich seaweed extract for a couple of days, trying to kick start the microflora and fauna in the system, introducing the nutrient so that organisms could begin to grow.

The inoculating of the grow beds was a simple process, I stirred the gravel in an established mature aquaponic bed, this stirred up a large amount of sludge which I scooped up and sprinkled over the new beds. It's best to apply the bacteria rich sludge and water, to the new grow beds in the evening as the bacteria are kept out of the sunlight. Once the inoculant has been spread onto the bed it's a good idea to give the beds a quick hose down, just a light sprinkle, enough to wash the bacteria from the surface, into the bed.

Planting the beds

I like to plant a variety of plants, and especially in the first crop for a new system you want to plant a little bit of everything to see what is going to be successful in the new system. Firstly I opened a number of packets of different herb and vegetable seeds and tipped them all into a bowl. Now I tried for a bit of everything, even things that shouldn't really grow well in a system like this, including carrots and turnips as well as other seeds which are known performers in aquaponic systems, silverbeet, basil, parsley etc. I spread this seed mix as evenly as I could over the beds wondering which would come up if any.

Figure 62: Germinating seed sprouting forth from the gravel.

Seedlings had to go in as well and as I hadn't had a chance to grow any seedlings myself I had to buy some. I don't want the beds to get clogged up with unnecessary organic matter so I had to wash the potting mix from the roots of the seedlings before planting then. In future I plan to use perlite to germinate my own seedlings before transplanting them into the beds, the perlite is easier to remove from the roots of the seedling, and it's not organic.

Figure 63: The stark contrast between a capsicum seedling and the red gravel.

The seedlings were very successful even though I had played with them and disturbed their roots I didn't lose one seedling out of the 100 or more which I had planted.

Stocking With Fish

The fish side of things can be looked into now, the plants need to get their nutrients from somewhere, and fish are going to be the source. Before adding expensive fingerlings to the system, it really needs to have time to get balanced and 'worn in', this is a good time to add the cheapest fish you can find into the fish tank. I went looking at goldfish which seemed to be the cheapest fish you could buy, but I still wasn't really happy as they weren't that cheap. When I mentioned to a sales person at the aquarium shop that I just wanted the cheapest possible fish he knew exactly what I needed, feeder fish. Feeder fish are basically goldfish that aren't gold, well I

guess they are more of a true gold colour than most goldfish you buy in the shops that are usually a bright red colour. Feeder fish are the more boring plain looking fish that doesn't catch a customer's eye, so they are destined to become feeder fish, bred and sold as feed for larger fish, they didn't even get a spot inside the aquarium shop, they were out the back in the stores area. Best of all, they were about one third of the price of the cheapest brightly coloured goldfish so I bought about 60 of them for the tank..

Figure 64: Feeder fish are a cheap way of initialising the system without risking loses of moire expensive fish.

If you have other larger fish in a different tank of some sort then the feeder fish make a useful source of food. I dropped a couple of the feeder fish into my other aquaponic system and they both disappeared within about thirty seconds. For some of the larger black bream in the tank, the small feeder fish were just one mouthful.

For the first few weeks of operation there isn't enough nutrient in the new system to support the plants and they will begin to yellow a little through lack of nitrogen, I compensated for this by adding a couple of capfuls of SEASOL seaweed extract and fish emulsion to the system every day by pouring it into the drain of one of the beds. This allows the nutrients to drain into the drain tank and then be pumped back into the fish tank mixing in well into the fish tank water. I kept adding the nutrients for about 4 weeks before I began cutting the nutrients back to every second or third day, while keeping an eye on the plants for signs of yellowing. If they seemed to be getting a bit yellow I'd add a little nutrient and within a couple of days the plants had picked up.

Detritus build up is a problem. Many aquaculture tanks have conical bottoms so that any sediment drops into the centre and is pumped out of the tank, but using a flat bottomed corrugated iron tank I had to find another method, especially considering that my pump doesn't sit on the base of the tank, I couldn't even push the sediment toward the pump to have it pumped out. I tried using large diameter garden hose to siphon out the sediment on previous occasions, but this wasn't highly successful. The hose tended to get clogged with leaves or chunks of detritus, causing the siphon to stop working, and it's not much fun sticking your mouth over the end of the hose and sucking on it, trying to get the siphon going again. In fact not only is it not much fun, but I'm sure it's a very unhealthy thing to be doing.

The drain fitting installed in my latest fish tank was a black plastic fitting which has about forty millimetres of threaded fitting poking into the tank, I had already attached a valve and garden hose to the outside of the tank for draining purposes, but how was I going to get the sediment from all over the base of the tank into this fitting which was about twenty millimetres off the base of the tank?

I took a gamble and bought some standard pool hose that is available from any pool shop and most large hardware stores, the hose almost fitted over the end of the fitting. I dipped the end of the hose into boiling water, then it slipped over the fitting effortlessly, then used a stainless steel hose clamp to clamp the hose on tightly. The hose is cut about two and a half metres long and at the other end of the hose I have wrapped wire around the pipe and attached it to a metre long stick, this allows me to direct the end of the hose around the bottom of the tank without getting a wet arm. When I've finished sucking up the muck off the bottom I just turn off the tap and top up the water level up in the tank a little, easy.

Figure 65: Pool hose attached to the drain fitting is used to clean detritus from the bottom of the tank.

After initialising the system and leaving it for about 3 months with only the goldfish in the tank, the weather was beginning to warm up as summer approached. This had raised the temperature of the water in the system to around 25 C, high enough for Barramundi to thrive. So the tank was stocked with about 100 Barramundi fingerlings. The fingerlings I bought were quite advanced being between 100 and 150mm in length, which was ideal for growing up to edible size in the limited time I had over summer. If I had bought smaller fingerlings there was a very real possibility that they may not have reached maturity before ambient temperatures began to decrease and their feeding would slow down as the water temperature dropped. The fish would also become more prone to disease with the decline in temperature, and heating the system in an open environment is just not feasible.

Once the fingerling were added to the system, the scrawny yellowing plants that were growing in the grow beds finally began to get more nutrient, and they started to boom.

Figure 66: A healthy crop of assorted greens.

Figure 67: Healthy tomato plants.

Heirloom tomatoes love the nutrient rich aquaponic water. These tomatoes I grew in small pots to begin with, before planting the pots directly into the gravel. This method seems to work fairly well, allowing you to plant fairly well established tomatoes into the grow bed, but you must be careful that the pots you use have large enough holes in the base to allow sufficient root growth into the gravel.

The bed in the back ground has been stripped of its old crop and replanted with seed. Still experimenting with different crops I have planted onions basil and corn. I know that basil grows very well in an aquaponic system, and last year I grew garlic in the grow beds successfully, so this year I'll see how the onions go. Care must be taken with corn seed selection. Most corn seed you might buy from a seed supplier will have been treated with a fungicide such as 'Thiram'. If your wanting to grow corn in your system, be sure to buy untreated seed as you don't want to risk contaminating your system.

Conclusions and my Thoughts

Food production needs to be brought back to the urban areas, we need to try to change our methods from buying all our foods from giant conglomerates, as this food is grown with only one goal, making money. When you look at the amount of energy required to grow/package/and transport the food to your table, the energy inputs far exceed any energy outputs which can be gained from the final food product it's a losing game no matter how you look at it, a nice looking product, with very little nutritional value and very little taste. Perhaps next time your in the supermarket and your looking at buying a small polystyrene tray of peas or beans take a few seconds to think about it, think of what has gone into putting that there in front of you, something which you'll eat in one meal and as only part of that meal. Firstly if you were to look into the production of the polystyrene tray and plastic covering and the energy required for their production and transportation, as well as the pollutions cause by the production and destruction of the tray, well I'm sure you get my drift. But then my main point is the actual food, the plants and the amount of energy required to produce the food. Surely you would think food is grown by plants gaining their energy from the sun. Here's one example of the amount of energy used in growing spinach, compared with energy available in the final product or crop.

Spinach, a green leafy vegetable, is valuable nutritionally since it provides iron, vitamins A and C and riboflavin. However, its commercial production is one of the least efficient in all vegetables: the output: input ratio is only 0.2:1, the overall energy cost being 53.5 million kJ/ha and the spinach yield being 12.1 million kJ/ha. This negative ratio means that about 21 kJ/ha of fossil fuel are "lost" to produce each kcal of spinach.

As for the other vegetables and fruits, the largest energy inputs are for nitrogen (50%), fuel and machinery. Ratios vary incredibly depending on the crop and method of growing. Apples aren't to bad having an output/input ratio of around 1.1:1, so your getting out of it about 10% more than the energy going into it's production, and potatoes are similar at 1.2:1..

These figures are only for the production of the fruits and vegetables, then when we begin to factor in the packaging, transport and storage to get that food to our supermarkets and ultimately our tables we begin to push most foods under the 1:1 ratio, meaning that there has been more energy going into growing that apple your eating than you can ever get out of it yourself by eating it, and this doesn't take into account the side issues of pollution from transportation/petro-chemical inputs such as fuels, pesticides and insecticides, land degradation due to poor growing practices etc etc...

Even some organically grown fruits and vegetables can be very inefficient in energy usage vs. energy outputs. An organic grower who uses bat guano imported from south Africa, seaweed extract collected and processed and packaged in another country, and pelletised organic fertilizers, has a very high energy input with all of the transportation and manufacturing..

Part of the reasons I love aquaponic systems, once you have your system set up the only inputs are running the pumps and feeding the fish, and with water usage estimated to be at around one tenth that of conventional vegetable production, it's a very efficient method for growing plants.

Chances are if your reading this then I probably don't need to tell you any more about the advantages of home grown fruits and vegetables compared with supermarket bought food. Anyone who has ever 'grown their own', or known someone who has, knows the difference in flavour of home grown produce. Just the other day a friend of mine stated that he had grown some tomatoes in the back yard with his kids, and they were so proud that they had just eaten their first home grown tomato, but it was bland and not nice at all.. Well of course, he had grown seed from a supermarket bought tomato, these tomatoes have been bred to specifically be good

looking, regular size and shape and long lasting in storage, so far as taste and nutritional value goes, well these factors mean very little in the selection and breeding of commercial varieties.

An aquaponic system has so many advantages, it helps teach adults and children about nature and natural growing cycles, it saves you money, provides hours of enjoyment and allows you to have fresh and nutritious food incorporated into your diet.. It's only been in fairly recent years that researchers have been investigating the differences between commercially grown fruits and vegetables which have been sprayed with insecticides and fungicides, and organically grown vegetables and fruits, and the results coming out are quite astonishing. Cancer patients who are receiving treatments are recommended to go on organic diets, eating only organic foods, and results are beginning to speak for them selves.

And fresh fish, the benefits of eating fish are widely known and documented and an aquaponic system can easily provide a couple of fish meals a week to an average family, as well as providing a large percentage of the vegetables you'll need.

Thanks

Without a doubt the most important people I have to thank for my fore into Aquaponics are the Speraneo's, and the many people from around the world who have had input into the discussion group operated by Paula Speraneo. They have opened their house and their small business to anyone interested in the subject, to anyone who wanted to listen and learn. They saw aquaponics or 'bioponics' as they often term it, as a method to help the world become a better place, with a goal of not to make money, but to help others in similar ventures, and encourage others to think outside the square. The aquaponic mailing list has members from all over the world dealing with an incredible number of variations on the theme. People from all walks of life come together on the list to share ideas and debate, From professionals, to homesteaders, people working in correctional centres, people out to try and find ways feed the worlds needy, people out to make money from commercial ventures, and then just simple people like myself who think it's a great idea which needs experimenting with and investigating further.

My thanks go out to all these people, they know who they are, and I'm not going to name names, apart from Paula who spends so many countless hours keeping the aquaponic online 'family' on track and motivated

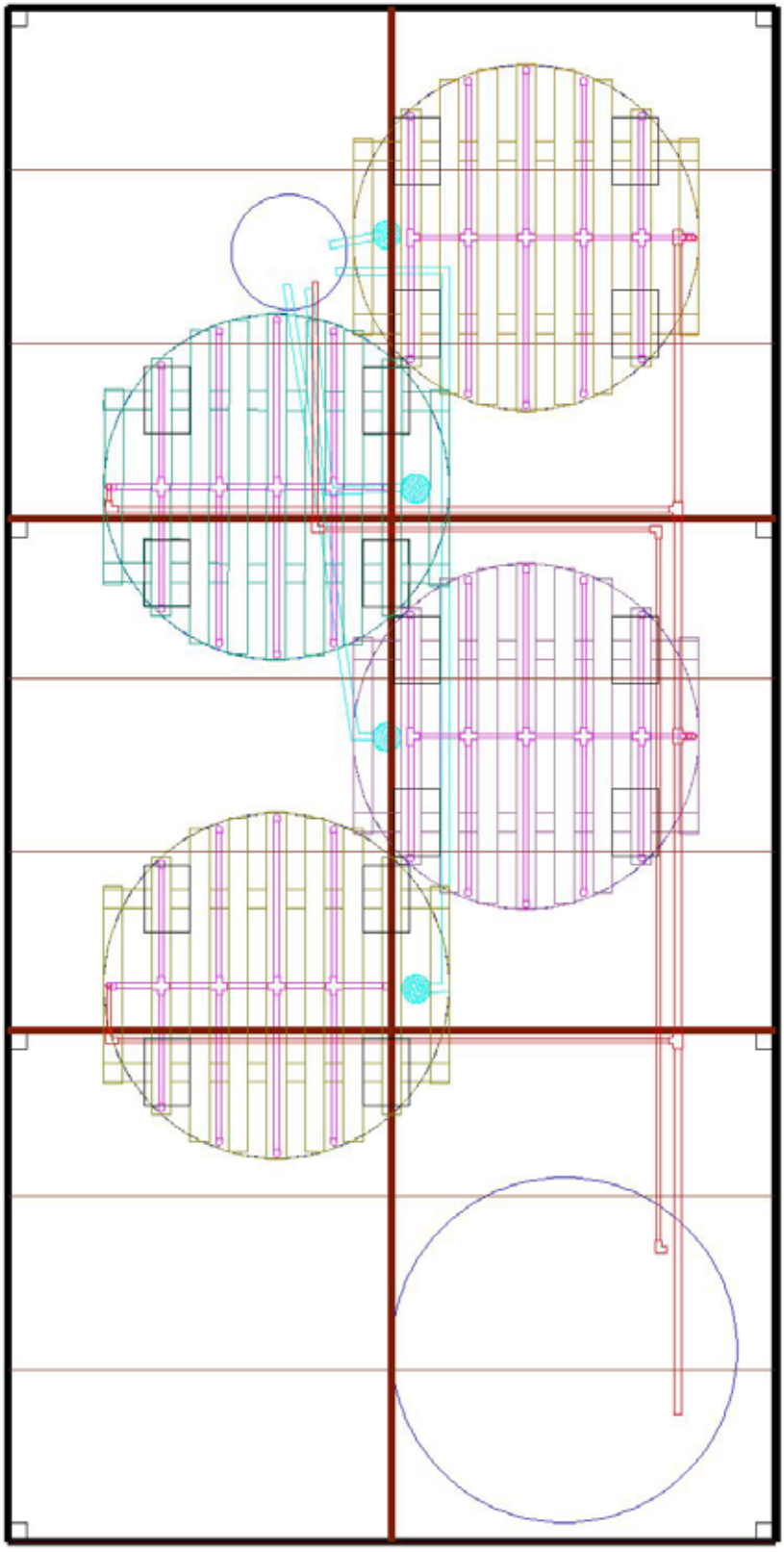
Might I suggest to anyone wanting to pursue the line of aquaponics further, that they join the aquaponics group, search the aquaponic archives for their wealth of information, and buy the Speraneos instructional book, video and plans which are available world wide from Paula Speraneo.

Thanks also go out to my friends and associates which have helped and inspired me along the way, many was the time I began to wonder what the hell I was doing spending all of my money and time on crazy aquaponic experiments. And all of those times when I was stuck with a particular problem and I couldn't see an answer, but verbal sparring, debating and fiddling with the aid of friends generally came up with suitable solutions to whatever design problem I had at the time. Thanks to Moonset Enterprises for giving me the chance to finish things off, and last but not least thanks to my mum and dad for the time they spend reviewing and correcting the original drafts of this book.

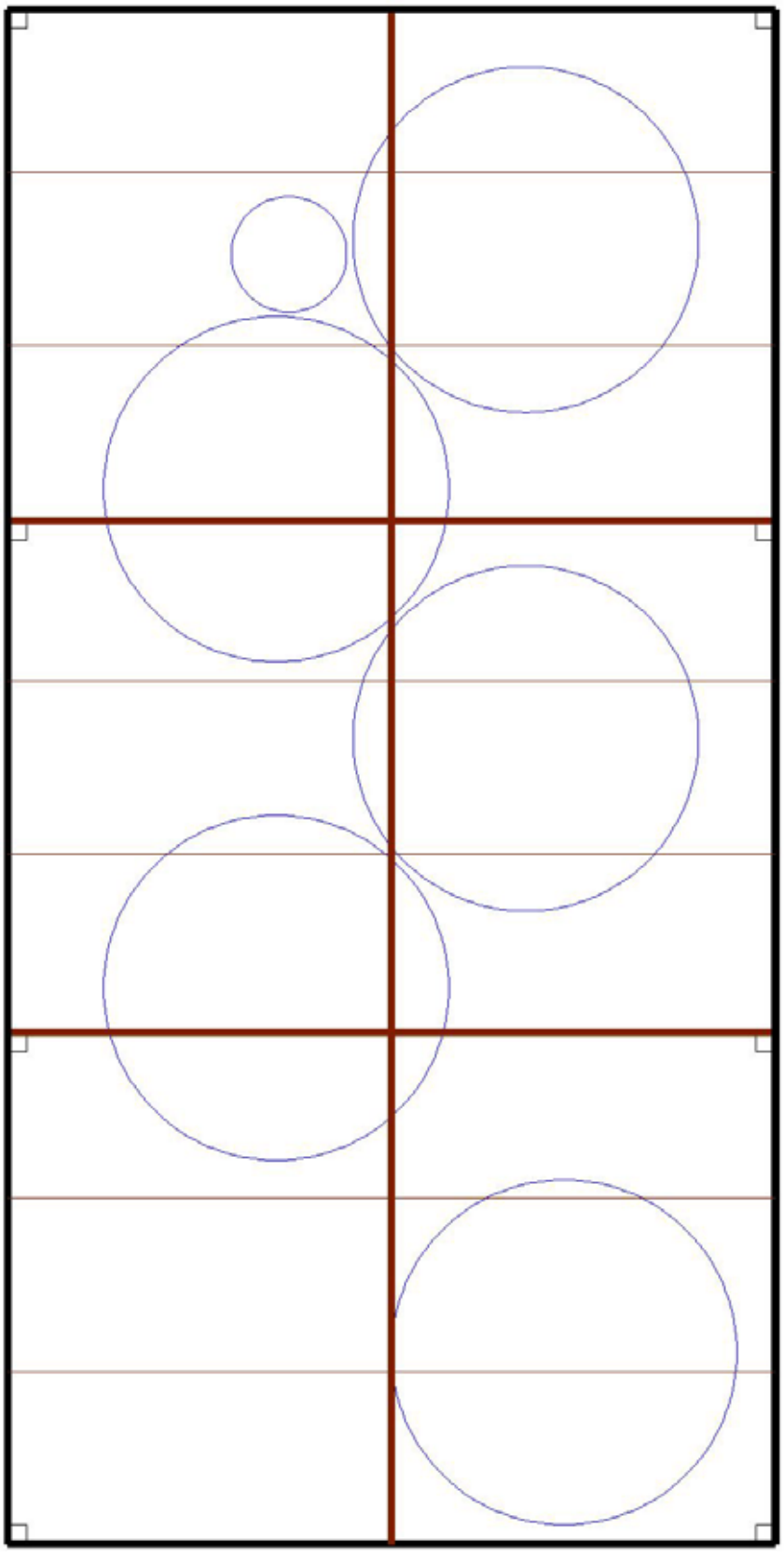
Design Plan

The following few pages contain the design drawings that I built my ebb and flow (flood and drain) system to. The design drawings include the pergola which housed the system and they are drawn to scale using CAD. No dimensions have been included on these plan diagrams but if you want to get an idea of approximate sizes, the pergola is eight metres long by four metres wide.

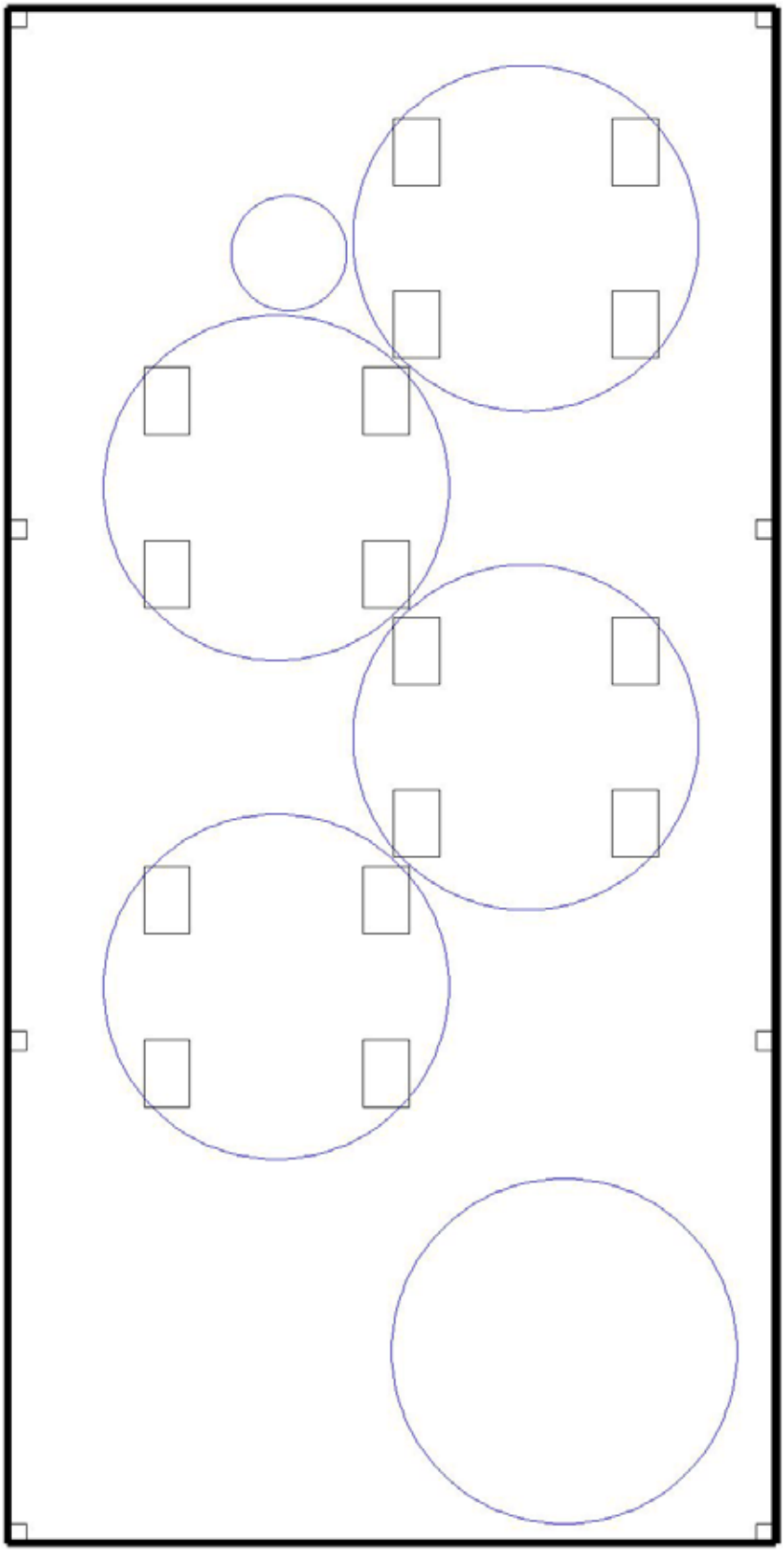
This design was based on what space I had in my backyard many combinations and variations are possible depending on your own situation, and the space you have available.



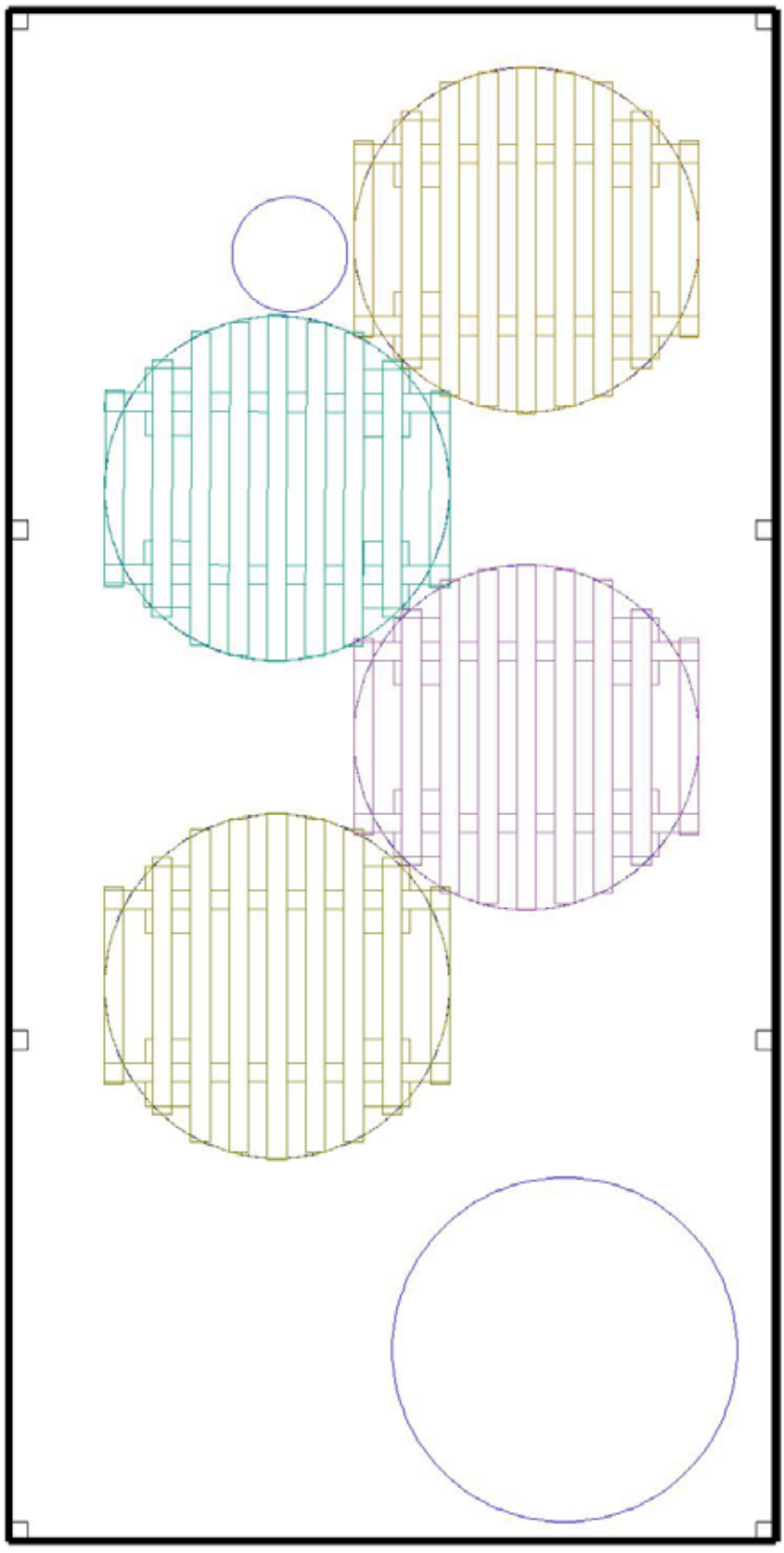
This plan illustrates all details of my current system in a plan view, overlaying each other.



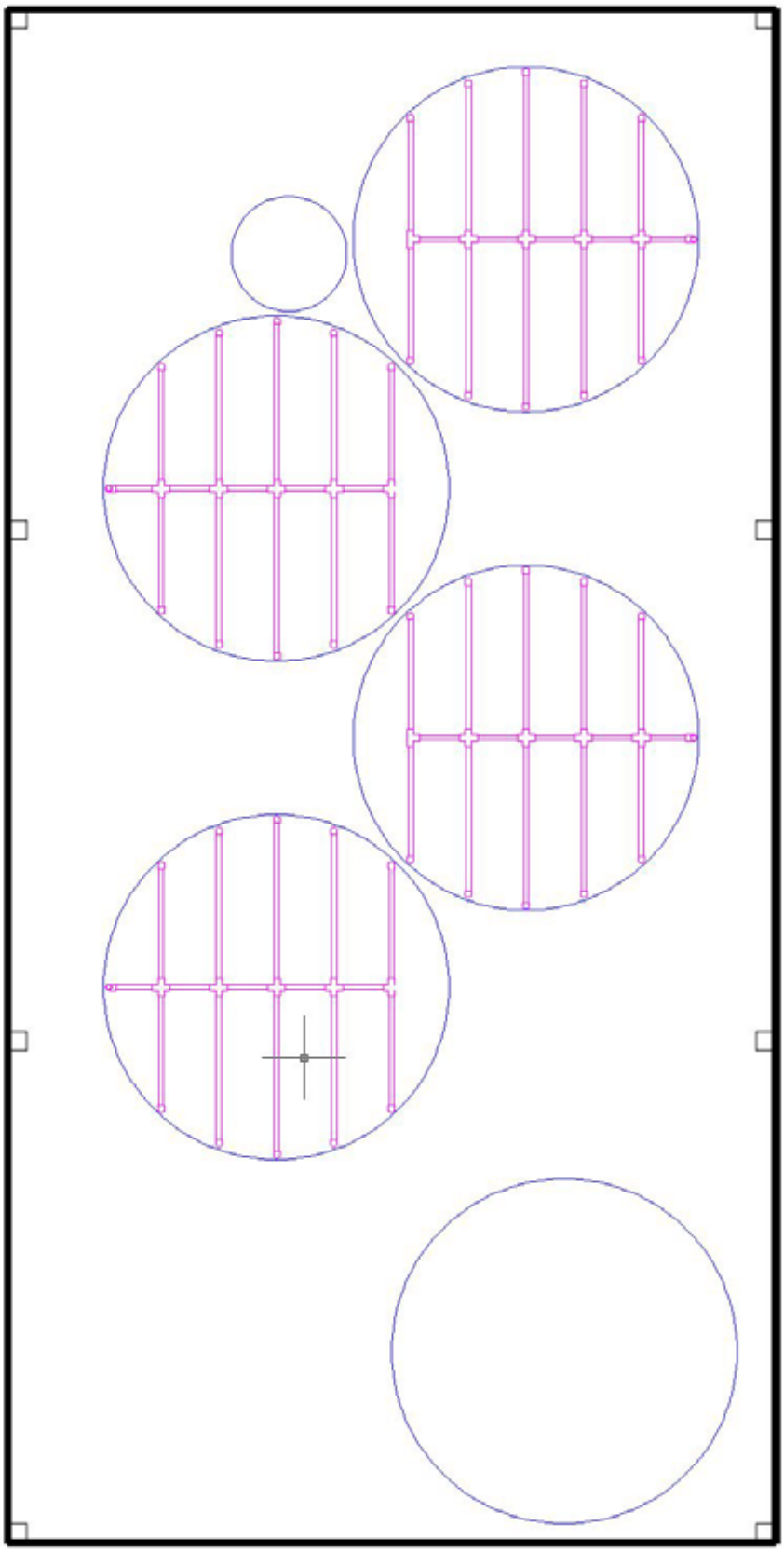
Layout of tanks inside the pergola.



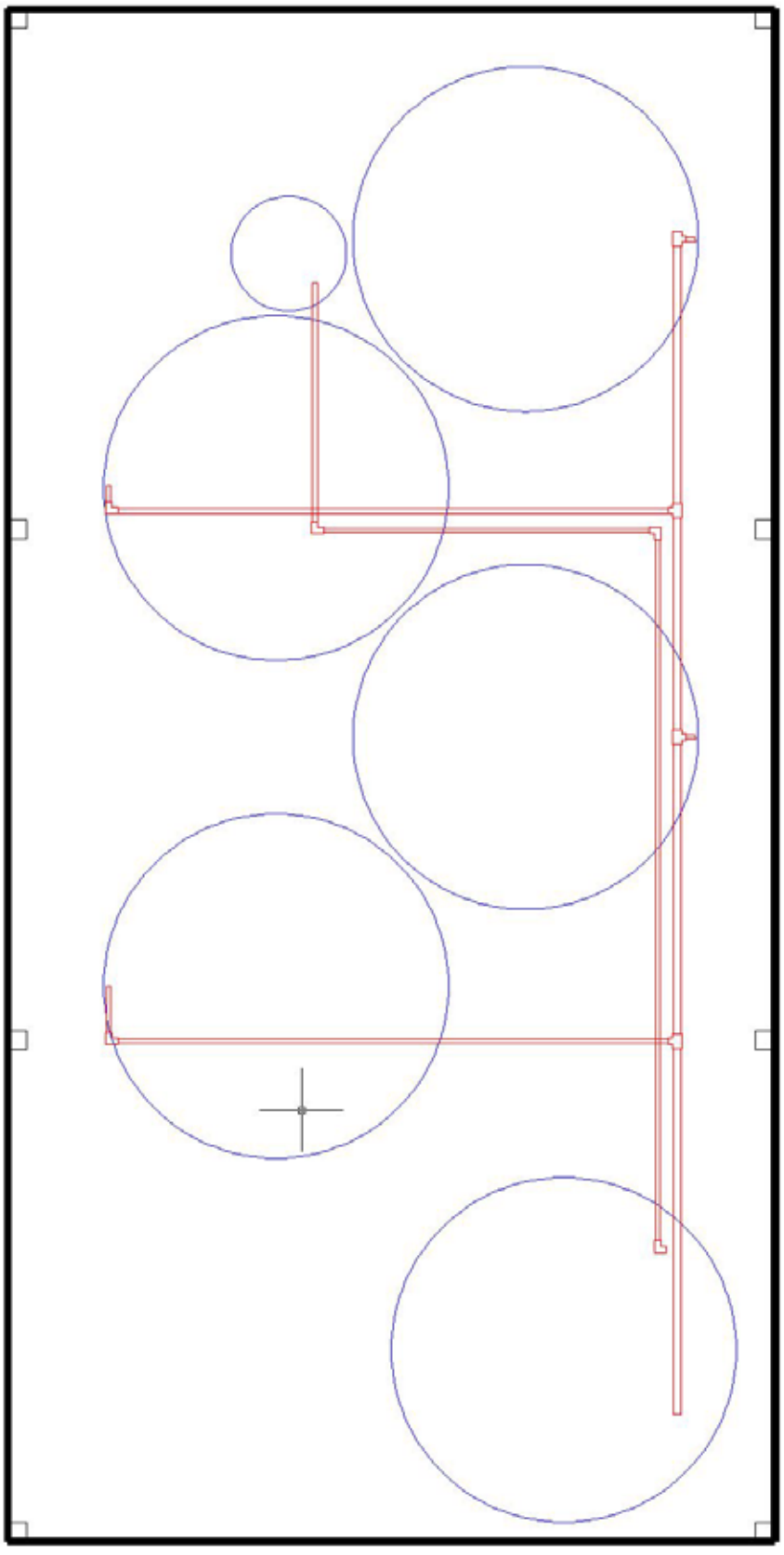
Positioning of limestone block grow bed supports.



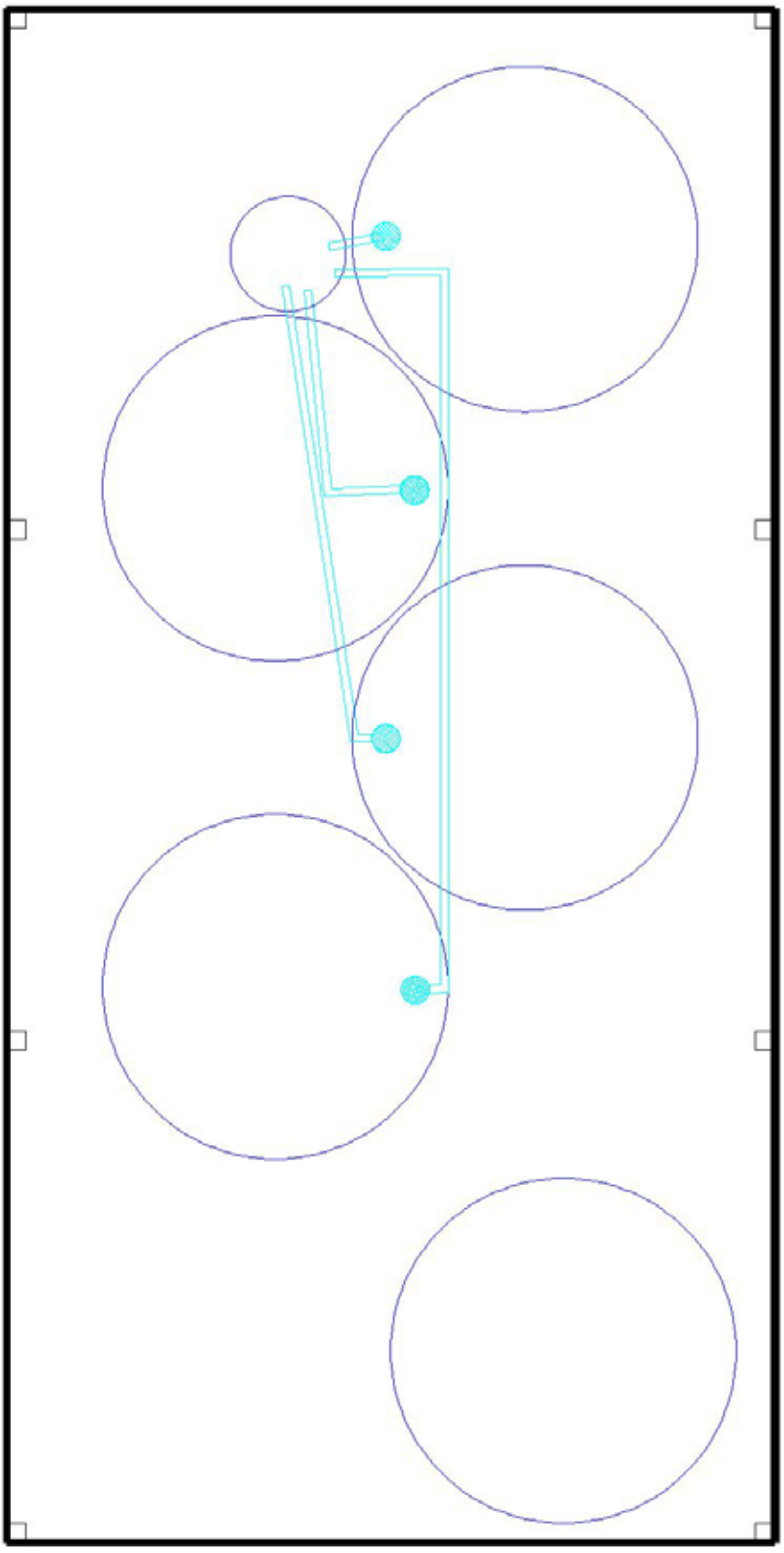
Timber supports for grow beds.



Irrigation grids.



Irrigation and return piping, located in roof.



Drain pipes, designed to fit around limestone supports.

Conversion Table

Metric length		**imperial**
1 millimetre [mm]		0.03937 in
1 centimetre [cm]	10 mm	0.3937 in
1 metre [m]	100 cm	1.0936 yd
1 kilometre [km]	1000 m	0.6214 mile
Imperial length		**metric**
1 inch [in]		2.54 cm
1 foot [ft]	12 in	0.3048 m
1 yard [yd]	3 ft	0.9144 m
Metric volume		**imperial**
1 cu cm [cm3]		0.0610 in3
1 cu decimetre [dm3]	1,000 cm3	0.0353 ft3
1 cu metre [m3]	1,000 dm3	1.3080 yd3
1 litre [l]	1 dm3	1.76 pt
1 hectolitre [hl]	100 l	21.997 gal
Imperial volume		**metric**
1 cu inch [in3]		16.387 cm3
1 cu foot [ft3]	1,728 in3	0.0283 m3
1 fluid ounce [fl oz]		28.413 ml
1 pint [pt]	20 fl oz	0.5683 l
1 gallon [gal]	8 pt	4.5461 l
USA volume		**metric**
fluid ounce	1.0408 UK fl oz	29.574 ml
1 pint (16 fl oz)	0.8327 UK pt	0.4731 l
1 gallon	0.8327 UK gal	3.7854 l
Metric Mass		**imperial**
1 milligram [mg]		0.0154 grain
1 gram [g]	1,000 mg	0.0353 oz
1 kilogram [kg]	1,000 g	2.2046 lb
1 tonne [t]	1,000 kg	0.9842 ton
Imperial Mass		**metric**
ounce [oz]	437.5 grain	28.35 g
1 pound [lb]	16 oz	0.4536 kg
1 stone	14 lb	6.3503 kg
1 hundredweight [cwt]	112 lb	50.802 kg
1 long ton (UK)	20 cwt	1.016 t

Complete parts breakdown for full system as of 2004 - 2005.

Number of	Item description	
Tanks n pumps n assorted bits		
4	tanks grow beds	
1	fish tank	
1	drain tank	
2	pumps	
4	Gravel	
1	tube silicon sealer	
1	roll thread tape	
1	pvc piping glue	
Supporting structure		
16	limestone blocks 500x350x240	
12	100x75 hardwood beams metres	
55	90x30 treated pine timber metres	
1	60mm nails	
16	180mm dyna-bolt	
Bed irrigation grids		totals
11	25mm poly pipe metres	44
4	25mm + pieces	16
10	25mm end caps	40
1	25mm elbow	4
1	25mm T-piece	4
1	25mm valve	4
General irrigation		
8	40mm pipe metres	
1	40mm non return valve	
1	40mm removable coupling	
2	40mm elbow	
2	40mm - 25mm T-piece	
1	40mm - 25mm reducer	
1	32mm - 40mm adaptor	
Drain system		
12	50mm DWV pipe metres	
4	50mm shower drains	
6	50mm DWV elbows	

2	50mm DWV 45 degree elbows
Water return	
9	25mm pipe metres
1	32mm - 25mm adaptor
1	25mm non return valve
1	25mm removable coupling
1	25mm T-piece threaded out
4	25mm elbows
1	40mm pipe metres
1	foam float
	Grand Total